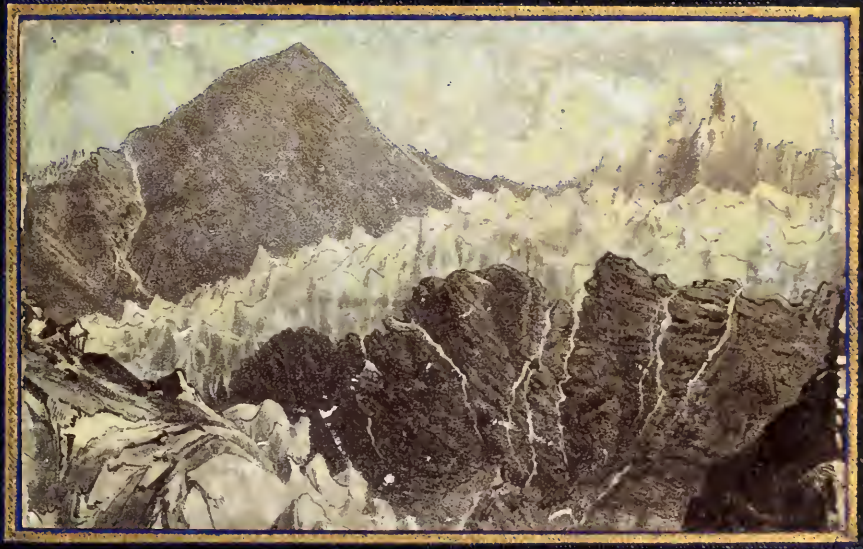
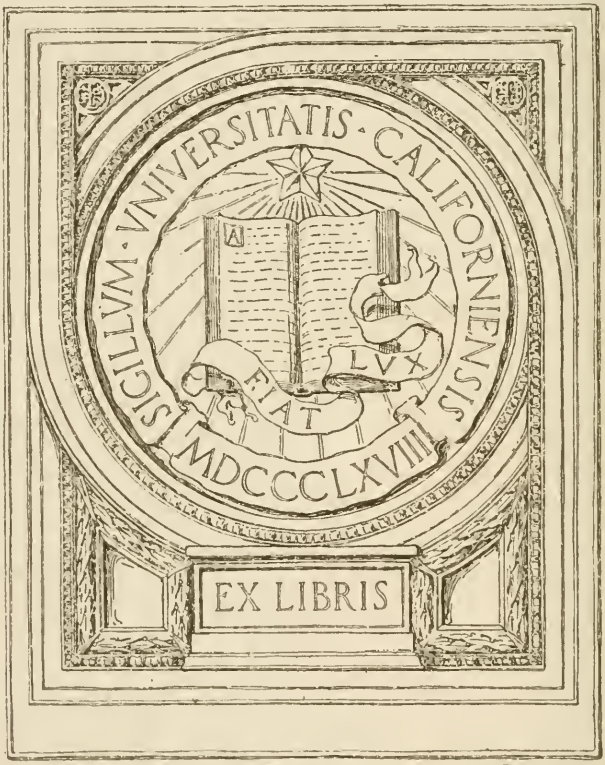
WONDERS OF THE PHYSICAL WORLD



THE GLACIER
THE ICEBERG, THE ICE-FIELD AND THE AVALANCHE

GIFT OF
Francis B. Sumner



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THE GLACIER OF SCHWARZE.

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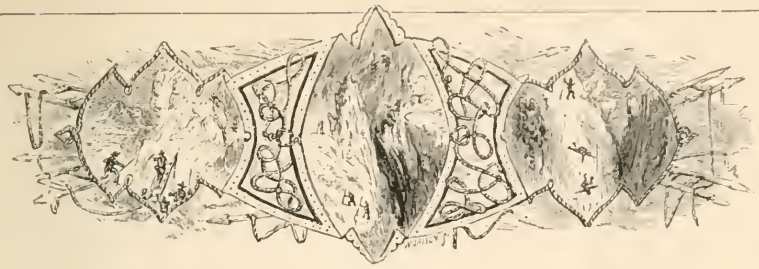

WONDERS OF

THE PHYSICAL WORLD:

THE GLACIER, THE ICEBERG, THE ICE-FIELD, AND THE AVALANCHE.

"Ye ice-falls! ye that from the mountain's brow
Adown enormous ravines slope amain—
Torrents, methinks, that heard a mighty voice,
And stopped at once amid their maddest plunge!
Motionless torrents! silent cataracts!
Who made you glorious as the gates of Heaven
Beneath the keen full moon? Who bade the sun
Clothe you with rainbows? Who, with living flowers
Of loveliest blue, spread garlands at your feet?"

S. T. COLERIDGE.

LONDON:
T. NELSON AND SONS, PATERNOSTER ROW;
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1875.

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Preface.

OF late years the study of Nature has come to occupy a recognized place in the curriculum of our schools; and it is no longer considered enough to store the youthful mind with Latin and Greek, and the drier details of History and Geography. An attempt is generally made to give it at least some faint idea of the phenomena which surround us, and to afford it an insight into the mysteries of Physical Science. And, certainly, the man who passes through life unobservant of Creation and its wonders, of the beauty of this "visible world," is so much to be pitied, that we cannot but hail with satisfaction the slightest efforts to teach the young the usefulness of an "observant eye."

Numerous text-books of Physical Science have been prepared by competent writers to render this study pleasurable and easy; but generally they are restricted in their scope, and, from the necessity they are under of being comprehensive, are meagre in their particulars. The present volume, and its companions, have therefore been compiled as *supplementary* to more precise and

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methodical treatises; the object being to dwell at some length on various aspects of Nature, and to describe them in a familiar and entertaining manner, with copious supply of anecdote, narrative, and illustration. Scientific accuracy, of course, has been aimed at in the statement of leading principles, and the setting forth of the results of modern research. But the thing mainly kept in view has been the collection of all such descriptive and entertaining matter as might convince the youthful reader of the profound *interest* of the studies to which it is desirable his attention should be directed.

In the following pages, derived from French and English sources, we seek to gossip discursively about the great phenomena of the Ice-World; about the glacier and its river-like motion, the iceberg and the ice-field, avalanches of ice, and deluges of snow. Unpretending as they are, they probably furnish a more ample supply of facts than can be found elsewhere in similar compass; and, at all events, it is hoped they will serve the purpose for which they were specially written, by inducing the reader to continue his investigations into the important subjects they discuss.

With these few words of explanation, we commend the present volume to the favourable consideration of the public, trusting that it will satisfactorily meet a well-known and acknowledged want.

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BOOK I.

GLACIERS.

I.

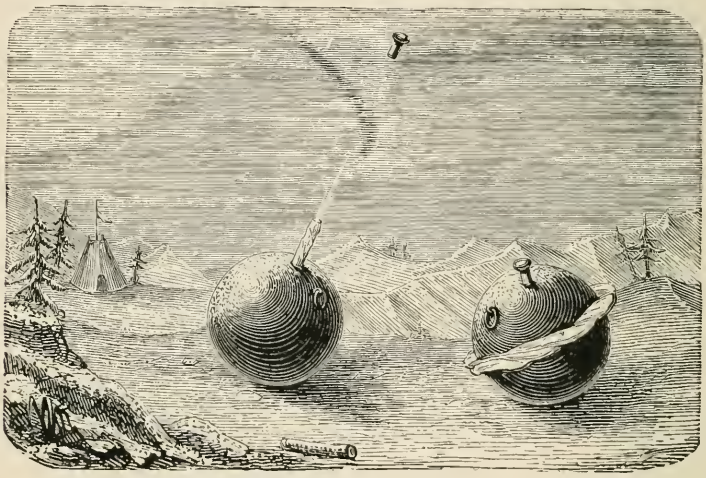
What is Ice?

CONGELATION OF WATER—EXPANSIVE FORCE OF ICE.

IN the phenomenon of the congelation of water, the ordinary course of Nature seems to undergo a check. The liquid, like all other bodies, diminishes at first in volume, but when it reaches the temperature of 32° F., or freezing-point, it attains its maximum of density. The process of contraction ceases, and in proportion as the cold augments the dilatation recommences. And, finally, when the water freezes, a sudden expansion is produced.

This expansion takes place with irresistible force. An iron vessel filled with water, and hermetically sealed, will burst into fragments if plunged into a freezing mixture. The tenacity of the metal is unable to resist the force

produced by the new arrangement of the atoms. A copper globe, filled with water, and firmly corked, will rend like a piece of silk if exposed to an atmosphere several degrees below freezing-point. The hardest rocks, if water be confined within their crevices, are shattered by the effect of the cold, justifying the popular adage: It freezes hard enough to split a stone.



THE EXPANSIVE FORCE OF ICE.

The formation of vegetable earth, or soil, must be attributed, in the main, to the expansive force of ice. The immense superficial stratum which nourishes the roots of plants, and in which all life is elaborated, is but the dust of the primary rocks, detached portion after portion, in the course of ages, by atmospheric agencies, and especially by the action of frost.

From another point of view, moreover, the extreme importance of the irregular expansion of water in the economy of Nature requires to be particularized. Let us

suppose a lake to be submitted to the effect of the cold night-air during winter, and under a calm sky. Its superficial water congeals and contracts. It becomes heavier, and sinks towards the bottom, whence rises a lighter water, which, after a while, grows cold in its turn. Thus, between the surface water and the bottom water a continual circulation is established, which, according to the ordinary law of densities, will only cease when the entire mass of the lake shall be transformed into ice; a transformation which entails the destruction of all the living creatures it encloses. But as below 39° F. water dilates, it is the cold water which rises and floats above the warmer strata; the solidification commences, and the ice extends but a small distance from the surface, vertically, forming a shelter and protection for fish and other animals.

If ice, when liquefying, contracts, the reason is, that the arrangement of its atoms requires more space in the solid than the liquid state. These elementary particles may be so disposed that greater intermediary spaces occur between their angles; and this effect of dilatation being produced by the cold, one is led to think that if the expansion of the mass were prevented by external pressure, it would remain longer in the liquid condition,—in other words, that the melting-point would be lowered. Sir William Thomson has demonstrated this fact by compressing a bit of ice between the plates of an hydraulic press. Certain indistinct striations were immediately revealed in the image projected by a ray of light which crossed this ice. While the temperature was maintained at 32°, these striations indicated liquid strata, whose sur-

face could be distinguished by the observer if he examined obliquely the interior of the block. Crystallization was therefore rendered impossible by the pressure, and manifested itself to be the true cause of the expansion of the ice.

ICE-FLOWERS.

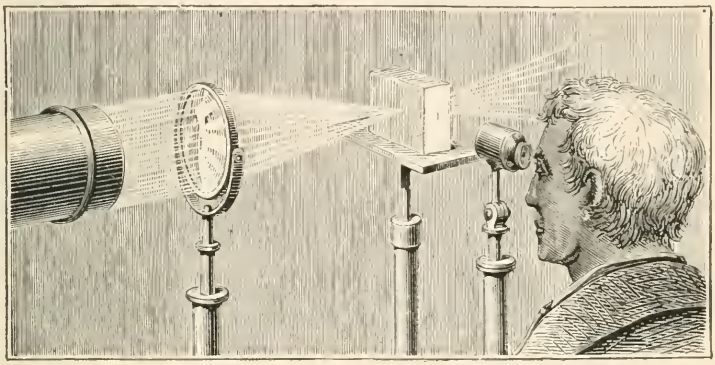
The peculiar part played by crystallization will be much better understood, if we cast, with Professor Tyndall, a more searching glance at the intimate constitution of ice.

At every temperature above 32° F., says our illustrious physicist, the motion of the heat suffices to keep the watery atoms disengaged from their rigid union. But this motion becomes so slack at 32° F. that the atoms then cling to one another, and unite in a solid. Not the less is this union subject to certain laws. To the majority of men and women a lump of ice seems to possess no more beauty or interest than a bit of glass; but to the enlightened mind of the scientific observer, ice is to glass what an oratorio of Handel is to the cries of the street or market. Ice is a music, glass a noise; ice is order, glass is confusion. In glass, the molecular forces have accomplished an inextricable labyrinthine network; in ice, they have woven a regular embroidery, the marvellous designs of which we wish to reveal to the reader.

How shall we contrive, continues Professor Tyndall, to dissect, as it were, this ice?

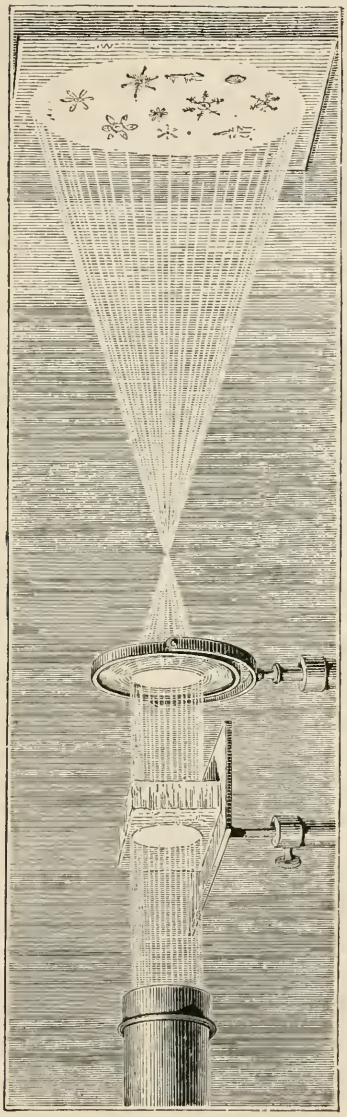
A ray of solar light, or, failing that, of electric light, will be the skilful anatomist to whom we intrust the operation. We launch this ray directly from the lamp across this transparent sheet of ice. It shatters into fragments the icy edifice, exactly reversing the order of

its building up. The crystallizing force had silently and symmetrically raised atom upon atom; the electric ray silently and symmetrically displaces them. We raise the sheet of ice opposite the lamp, and the light now passes



DISSECTION OF ICE BY THE SOLAR RAYS.

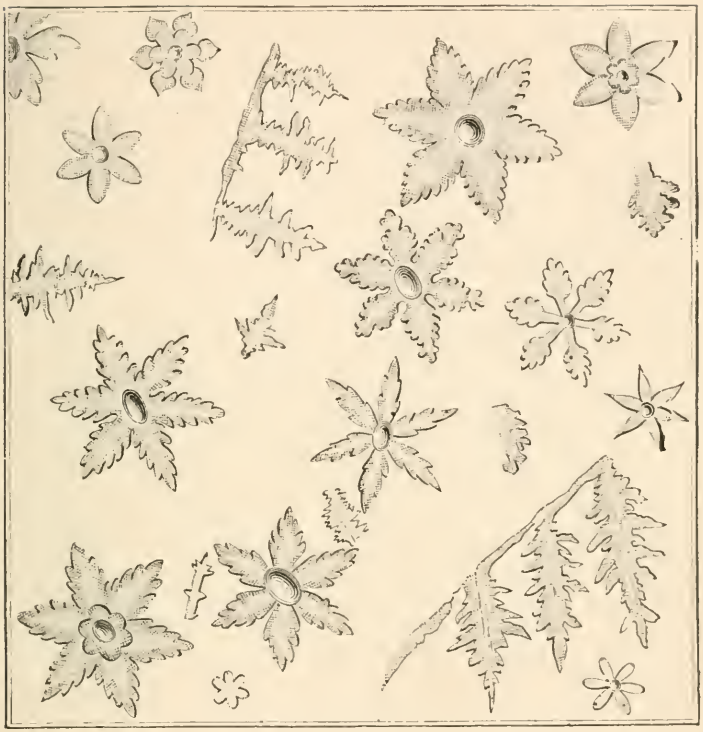
through its mass. Compare the entering ray with the issuing ray: to the eye there is no perceptible difference; the intensity of the light is scarcely diminished. It is not so with heat. On the contrary, the thermic agent, the ray, is far more potent before its entrance than after its emergence. A portion has been arrested in the ice, and this portion is the anatomist we would fain set to work. What will it do? We place a lens in front of the ice upon a screen. Observe the image produced; an image, however, whose beauty is far inferior to that of the reality. Here you see a star; there another; and, as the action of the heat continues, the ice appears more and more to resolve itself into stars, all six-rayed, and all resembling lovely flowers. By moving the lens to and fro, we bring new stars into sight; and, while the action lasts, the edges of the petals are covered with indentations



EXHIBITION OF ICE-FLOWERS BY PROJECTION.

like those on the leaves of a fern. Probably, few of our readers have hitherto had any idea of the beauties concealed in a block of ice. Yet consider, prodigal Nature works in this manner throughout the whole world. Each atom of the solid crust which covers the frozen lakes of the North has been formed according to the law we have just explained. Nature arranges all things harmoniously, and it is the mission of Science to render our organs capable of appreciating her concords.

Now let us direct the reader's attention to another interesting point of this experiment. You see these flowers illuminated by the light which traverses them. But if you examine them, by allowing a ray to fall *upon* them, so that they shall reflect it and return it to your eye, you will see in the centre of each a spot which has all



ICE-FLOWERS.

the lustre of burnished silver. You will be tempted to think this spot a bubble of air; but by immersing it in hot water you can melt the ice all around the spot; and at the moment that *it* alone remains, you will see it lessen, and finally disappear, without any trace of air. The spot is a vacuum. See with what fidelity to herself Nature operates, and how, in all her operations, she is rigorously bound by her own laws. We know that ice, in melting, contracts; and here we seize upon this contraction in the very fact. The water of the flowers cannot fill the space occupied by the ice which by its liquefaction

has given birth to them: hence the production of a void, the inseparable companion of each liquid flower.*

Is this fragment of compact ice, the elements of which are gifted with such fine forms, itself a crystal,—that is to say, a body composed of crystalline molecules all set in the same direction? Sir David Brewster answered this question by employing as his means of analysis the modified light which we call *polarized light;* a light well adapted to bring out the peculiarities of the internal constitution of substances, through the coloured figures which this light defines upon a screen, after having traversed them. All crystals with an axis—like Iceland spar, for example—yield a series of rings of brilliant colours, traversed by a very regular cross, completely black. As ice furnishes the same figures, we are necessarily led to attribute to it the same kind of crystallization. We must remark, however, that in this connection we are referring only to the thick ice formed upon our canals and lakes. If we took the *first* stratum which made its appearance on the surface of the water, we should discover it a most irregular crystallization; the shaft of polarized light producing nothing but a mosaic of various colours, arranged without any order. It is easy, however, to account for the formation of this stratum. The portions of the fluid mass in contact with the air are necessarily the first to freeze; but each molecule of ice gives up something of its heat to the adjacent water, which therefore grows slightly warmer, and a partial congelation is the result. The surface, if then observed, presents a

* Tyndall, "Heat Considered as a Mode of Motion."

multitude of fine needles crossing each other in every direction, and forming, as it were, a network of ice, the interstices of which gradually fill up. When the network is converted into an unbroken sheet, the loss of heat is more and more diminished as this envelope, or wrapper, grows thicker and still thicker; but the development of the ice has continued in the form of long interlacing needles, as may be seen by removing a portion, and examining its interior configuration.

In cold countries the frost, as everybody knows, covers the window-panes of our apartments with beautiful designs. And a crystallization of a similar kind to that which we have been describing, develops on the glass a variety of palms and ferns of ice with delicately woven branches, crossing and entangling in each other, as in the labyrinthine recesses of a forest.

ICE-CAVERNS.

In the mountainous regions we meet with grottoes or caverns so disposed that the air remains stagnant in them, at a low temperature. Water penetrating slowly, and sometimes drop by drop, through the fissures of the roof, congeals into masses of ice rarely submitted to a partial thaw. These masses, when numerous, constitute a valuable provision in summer, and moreover, through the agency of their concretions and crystallizations, present a very beautiful decoration. We shall quote from a French author his description of the ice-cavern of Fontcurle, situated in the Department de la Drôme, to the north of Die, and on the edge of a plateau elevated 5500 feet above the sea-level. The cavern enclosing it is not more than

200 feet in length; but as the ground slopes considerably towards the north, we presume that on this side it communicates with other caverns of the same mountain. For the entire length of the grotto, the calcareous stalactites

ICE-CAVE OF FONTEURLE.

suspended from the roof droop down to the very earth in the form of folded or embroidered draperies. In the centre stands a mass of sloping ice, composed of small hexahedral crystals, or six-faced prisms, limpid as rock-crystal. Upon this frozen basin descend from the top of the grotto a number of hollow stalactites, likewise of

diaphanous ice, and crystallized into miniature fissures; thus, the interior of the grotto seems entirely composed of crystal, while natural sculptures of alabaster decorate its walls.

To enjoy all the beauty of this spectacle, you must light up the interior of some of the columns of ice, as was done by a company of travellers who visited the glacier in 1805. Then everything sparkles, and coruscates, and reflects the most brilliant gleams; you fancy yourself transported into a palace of diamonds, rubies, and topazes, such as one reads of in the Arabian fictions.

It is unfortunate for the curious visitor to the ice-cave of Fonteurle, that the natives of the surrounding district fully understand the value of this deposit of natural ice; and work it in summer, absolutely without expense. Those who first entered the grotto enjoyed a spectacle which Nature had been preparing for ages, but of which the visitor now-a-days sees only the poor remains.*

In a well-known scientific publication,† another French writer, M. Héricart de Thury, describes a visit which he paid to this cavern. He found the huge stalactites completely void, forming so many hollow shafts, but decorated internally with beautiful circular crystallizations. An attentive examination showed him that all of these crystals were not hexahedral prisms, but that some were triangular. In many specimens of hexahedral prisms, with a diameter of 0^{m} 005, the terminal edges, at the junction of the base with the lateral faces of the prism, were replaced by facettes. Nowhere could he discover a complete pyramid.

* Depping, "Merveilles et Beautés de la France."
† "Annales des Mines," tome xiii.

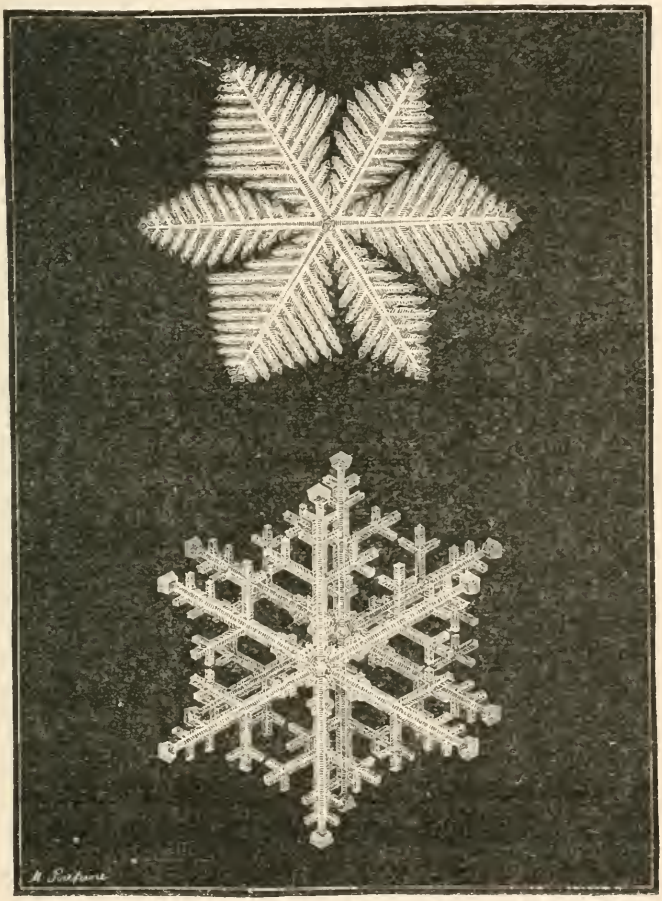
Messrs. Pictet and Colladon, two Genevese naturalists, furnish similar details in reference to the ice-caves of the Jura. That of St. George, 2800 feet above the level of the Lake of Geneva, presented, at the close of July 1822, a frozen surface of 80 feet in length, with a maximum breadth of 45 feet. All the grottoes visited by these naturalists were arranged in such a manner that the renewal of fresh air was almost impossible; and this circumstance accounts for the extreme slowness with which the great masses of ice accumulated in them during severe winters melt. Owing to its great density, compared with hot air, cold air maintains itself in cavities where no current can be created, and where the earth, always a bad conductor of heat, does not allow it to penetrate. The temperature ascertained in the interior of the ice-caverns during the hottest months of the year is only 34°; and several summers are needed, therefore, to melt the accumulated ice, even in cases where it is not renewed each winter.

ATMOSPHERIC ICE.

The six-petalled flowers which, under the influence of a ray of sunshine or of a beam of electric light, spring spontaneously into being in a block of ice, are likewise found in a flake of snow, when it is submitted to microscopical observation.

In the bosom of the calm air prevailing in the upper regions of the atmosphere, the aqueous particles form the most graceful and varied figures, though all are constructed on the same type. They are, uniformly, hexagonal stars. From a central nucleus radiate six needles, forming, two by two, angles of 60°, and generally marked

by various indentations which possess the same angle. Frequently these needles terminate in secondary centres, likewise surrounded by regular hexagons. The combina-



SNOW-FLOWERS.

tions of these geometrical elements are innumerable, and depend on the intensity of the cold during the formation of the snow. The greatest variety is found in the Polar

Regions, where Dr. Scoresby detected upwards of two hundred entirely different figures. Their form often varied from one shower of snow to another. And as the temperature fell, the crystallization became more complex, without ceasing to exhibit a perfect regularity. In very severe frosts, and under a serene sky, these flowers of snow diffuse a vivid splendour, by reflecting the solar rays on their myriad sparkling facettes.

The snow, when spreading over our fields, forms an admirably efficacious protection for the seeds confided to the earth against the action of a severe frost. You may notice even upon the mountains a quick and living vegetation under the snow. The solar rays which strike a lofty peak have lost much less of their intensity through the absorption of the atmosphere than those which descend into the plain; they warm the soil more thoroughly, and propagate or diffuse themselves from point to point by melting the frozen strata which they touch. Frequently the traveller, by planting his foot on the edge of a snow-field, breaks the superficial crust, and uncovers a number of beautiful Alpine flowers, nourished by the heat under the mantle which defended them against the occasional frosts that always accompany bad weather on lofty mountains. On the other hand, the weight of the snow often proves very injurious to vegetation. In the south of France, tall pines have been known to break under the thick, heavy burden with which a sudden hurricane has loaded their branches.

Ice also appears in the atmosphere in the form of hail. It precedes or accompanies storms of rain. If the dimensions of its globules cease to be very minute, it becomes

a formidable scourge for agriculture, and even threatens, at times, the lives of men and the larger animals. There is abundant evidence to prove that hailstones have fallen which weighed upwards of eight ounces. As a rule, these stones are spherical or lenticular. The angular form is rare. A nucleus of fibrous snow occupies the centre of each hailstone, and around it is discernible a larger or smaller mass of diaphanous ice, and sometimes strata alternately diaphanous or opaque. The radiating structure appears completely exceptionable.

REGELATION OF THE ICE.

The late illustrious physicist, Professor Faraday, excited the curiosity of scientific students, some years ago, by a remarkable experiment. Having divided into two parts a fragment of ice, he brought the divisions together immediately their surface began to melt, and they united immediately.

This result, which may be produced even in hot water, is explainable as follows :—

When the temperature of water rises, the superficial molecules first become vapoury, then gaseous ; being out of the range of the coercive action of the surrounding molecules, they are easily set at liberty ; transported, on the contrary, to the centre of the mass, they are completely exposed to the influence of this action, which determines a new solidification,—that is, according to the expression usually adopted, a *regelation.*

Hence we are enabled to demonstrate what varied forms may be given, by simple pressure, to a fragment of ice. By placing a horizontal bar in moulds, each of which has

a greater curve than its predecessor, it may easily be reduced to the shape of a ring or even of a knot. In each mould the ice breaks, but if we continue the pressure the surfaces of the various fragments come in contact, and adhere to each other so as to re-establish the continuity of the mass. A ball made of moist snow, kneaded by the hand, soon hardens into a sphere of ice, which may be easily moulded into a cup, a statuette, or any other device.

Professor Tyndall refers to a remarkable example of regelation which he observed early in spring. A stratum of snow, one to two inches thick, had fallen on the glass roof of a small conservatory, and the internal air, warming the windows, had thawed so much of the snow as was in immediate contact with them. The entire stratum had glided down the frame, and overhung the edge of the roof, without falling, and progressively forming in folds like a flexible body.

According to the same physicist, it is by this single fact of regelation that it becomes possible to cross upon bridges of snow in the higher districts of Switzerland. "By ascending," he says, "and cautiously walking upon the mass, we determine the regelation of the grains of snow; the mass then assumes a rigidity which, but for the act of congelation, it would never have attained. To those who are not familiarized with this kind of labour, the fact of crossing upon bridges of snow, as is frequently done, crevasses upwards of one hundred feet in depth, appears completely terrifying."

GLACIER ICE.

The snow-fields which we meet with on the summit of

every glacier are composed of crystallized snow, the frail architecture of which endures so long as it remains dry, but undergoes a great transformation when the sun, melting the superficial stratum, insinuates water into its substance. The liquid, congealing anew during the night, causes the snow to pass into the *névé* stage; *névé* being the name which the Swiss physicists have given to a granular mass composed of tiny round grains of ice, disintegrated still, but more adhesive than snow-flakes, and in density preserving a medium between that of snow and that of ice. Under the pressure of the new strata, and owing to successive infiltrations of water, the *névé* unites, and becomes a more and more compact ice, which, in the end, exactly resembles that of the lakes and rivers of the plains. A distinguished physicist, M. A. Bertin, has recently studied among the Alps these variations in the constitution of the glaciers, with the agency of polarized light, and has ascertained that, in effect, they are incessantly tending towards the stage of crystallization which forms perfect ice. In the upper regions, on the Faulhorn and the Wetterhorn, the direction of the molecules seemed to him to be null; it was scarcely perceptible in a very recent glacier, like the higher glacier of the Grindelwald; but if the ice had had time to grow old, as in the lower glacier, the mass of water congealed in the interior acquired the preponderancy, and the setting of the crystals was manifest.

Ramond, one of the earliest explorers of the Alps, in the notes to his translation of Coxe's "Letters upon Switzerland," furnishes the following description of this phenomenon :—

The loftiest mountains, he says, those to which the name of *glaciers* particularly belongs, are absolutely inaccessible; but the trained eye distinguishes in the dazzling whiteness of their vestments that *deadness* which characterizes snow. In fact, it falls from the clouds only as snow; and that which clings to these lofty summits, being unable to experience a real thaw, must remain under this form, or cover itself simply with a light varnish of imperfect ice, caused by the agglomeration of the parts of the surface most exposed to the sun. This resplendent crust it is which has deceived some observers as to the nature of the garniture of these mountains. Every portion of the said garniture is very easily detached, and frequently falls in frozen dust to the bottom of the neighbouring valleys. Such is the first stage of the upper snows, and the first step which they make towards the lower valleys.

Directly beneath these mountains, and in the elevated basin which receives both their refuse and the snows of the atmosphere, the temperature is less glacial, the sun has some degree of influence, and a few days' thaw suspends the rigour of winter; there we find the snows more condensed and more adhesive; they already are strong enough to sustain the foot, but they still retain its trace. Behold the immense reservoir whence the glaciers derive their substance! An infinity of branches escape in every direction along the scooped valleys descending towards the plains. Their snows, elaborated in the upper basin, and grown more solid, are able to support the test to which a somewhat more temperate region will submit them. The second step is accomplished.

In their new abode, the snows are exposed to longer thaws, but the frosts are not less bitter. Their mass is more and more interpenetrated with the water produced by the dissolution of some of their parts; when it is thoroughly absorbed, the cold surprises it, and transforms the whole into a kind of half-ice, which has already a certain degree of transparency: here springs the glacier.

The work is not yet finished, but it tends rapidly towards perfection. Each fathom of descent towards the lower region gives to the ice an additional hardness and transparency, and soon the glacier in its complete transformation retains no trace of its origin.

If, however, we examine attentively the part where the work is most complete,—that is to say, at the foot of the glacier,—we shall perceive that it does not yet form an entirely homogeneous whole, but is composed of two different kinds of ice. That which forms the lower stratum is more compact and more transparent there, and of a hardness which surpasses that of our most perfect ices; in all other respects it is identical, and, when struck lightly, it breaks into angular pieces terminated by plane surfaces; but that composing the irregular fragments strewn over the upper superficies is whiter, lighter, and less solid, dividing only into globular fragments, which in themselves are simply an aggregation of similar parts. The lower ice is there, the product of water regularly crystallized; while the upper is as yet but *snow*, the particles of which have been blended together by a succession of frosts and thaws.

It is the inferior ice, as seen in the interior of

crevasses, which wears the beautiful azure tint so admired by travellers. Among the various kinds of mountain ice, observes Ramond, one has been remarked of a very deep blue colour, which greatly surpasses in hardness, weight, and in indissolubility, the most solid ices we are acquainted with. These properties are owing to its antiquity, and the continual succession of dissolution and congelation which it has undergone. Its particles have gradually drawn together; it has expelled or dissolved all the particles of foreign air which disturbed its transparency and diminished its adhesiveness; remaining, therefore, without admixture, it has acquired the blue colour, which is the colour of air and water where they are seen in a mass, and where they hold no other fluid in suspension.

STRATIFICATION AND VEINED STRUCTURE OF ICE.—SÉRACS.

Many other curious particulars are noticeable in glacier ice. Each abundant fall of snow on the mountain-summits forms a stratum easily distinguished from preceding strata, which have ordinarily passed into the condition of *névé*. This stratification becomes more apparent when the whiteness of the surface has been tarnished by dust deposited by the winds. It is still perceptible in the ice, but must be carefully distinguished there from another phenomenon with a different origin, which has been long confounded with it,—the veined structure.

In localities where through an accident the glaciers are cut almost vertically, you perceive upon the section a series of parallel veins formed by beautiful transparent

blue ice in the midst of the general whitish and somewhat opaque mass.

From glacier to glacier, and from one part to another of the same glacier, the number of the veins and the intensity of their colour are variable. They present especially an admirable aspect when seen in the newly-opened crevasses, and on the sides of channels hollowed in the ice by small brooks resulting from the superficial fusion. Some glaciers—as that of the Rhone, for example—present this veined structure over nearly their whole extent. When a vertical cutting exposes the whole of the veins to the air and the rain, the portion of less density disappears prior to the blue ice, which then remains in separate laminæ. If we attentively examine the latter, we remark in them the absence, or at least the extreme rarity, of air-bubbles, while the whitish ice contains them in great numbers.

Professor Tyndall has succeeded in explaining the formation of the veins by a method which, at the first glance, appears curiously indirect. In an excursion to the slate-quarries of Wales, he took occasion to study the *cleavage* of the rocks composing them; that is to say, their faculty of dividing naturally, a property common to all crystals. The schistous slate separates readily into leaves; and if you traverse several quarries you will see that the planes of cleavage are identical in all. This circumstance, at the outset, had suggested to naturalists the idea of looking upon the slates as products of the stratification of successive deposits. But Professor Tyndall would not accept this explanation when he saw that the microscopic fossils which they enclose are con-

stantly shapeless and flattened in the direction of the plane of cleavage; for they could not have experienced so great an alteration in strata superimposed upon one another at the bottom of a liquid.

He concluded, therefore, that these schists must have been subjected to a considerable pressure; and more, that this pressure could be exercised only at right angles with the plane of separation of the laminæ. By repeated experiments he found that many bodies, when subjected to a heavy pressure, present a very marked lamination in their structure, and frequently veins of great beauty. He examined iron which had been flattened by the steam-hammer, or passed through the flattening-mill; clay and wax were subjected to the action of the hydraulic press. In all these materials the cleavage was conspicuous, and hence the phenomenon may rightly be considered the constant result of pressure upon all bodies with an irregular interior structure. It is the same with glacier ice, from the mass of which are gradually expelled the bubbles of air intermingled with the snow. White at first, it assumes in the parallel strata corresponding to the planes of cleavage the beautiful blue tints which characterize the veined structure. It has so little to do with stratification, that in places where the latter is apparent—as, for example, the glacier of Aletsch, visited by Professor Tyndall—it has given rise to a series of horizontal lines, while the parallel veins which extend in the same masses of ice are all inclined at an angle of about 60°.

This tendency to cleavage in compact ice seems to account for the regular form of the more or less massive débris with which the glaciers are covered. These, most

frequently, are cubes or rectangular parallelipipeds. The mountaineers call them *séracs*, on account of their resemblance to certain cheeses which bear this name, and which they manufacture in rectangular cases. De Saussure, during his ascent of Mont Blanc, traversed a considerable area strewn with these *séracs*, which had been detached from a neighbouring glacier. Many of them measured 12 to 14 feet in every direction. Other travellers have met with enormous cubes of 50 feet, as regular as if they had been fashioned with a chisel.

In the crusts of ice which cover the lakes, the traces of strata formed during successive frosts are sometimes preserved very distinctly, when these frosts have occurred during a period of perfect tranquillity. We owe the following example to Arago * :—

In withdrawing, he says, in the winter of 1821, from the huge ice-masses of the lakes near Newhaven (North America), we remarked, in blocks about 0^m 38 thick, one-and-twenty distinct layers, as clearly defined as are the bands of agate or jasper, or the concentric rings in the trunk of a tree. Towards the top the thickness of the strata varied between 0^m 025 and 0^m 037 ; at the bottom, near the water, it did not exceed 0^m 012 or 0^m 018. The decrease in thickness, though not uniform, was indubitable. If we compare the extreme thickness, and take into consideration the fact that the cold, instead of diminishing during this successive formation, was constantly increasing, we remain convinced that the differences have arisen from — 1st, the heat-conducting faculty of ice being very small ; and 2nd, from the ice

* "Annuaire du Bureau des Longitudes," 1833.

not forming in a continuous manner under the first stratum, but only at the coldest moments of the night. The strata were more transparent in the direction of their length than in that of their depth. At the junction of the two contiguous strata might be seen a multitude of air-bubbles, for the presence of which it is easy to account.

GROUND ICE.

The congelation of lakes and ponds takes place, as we have pointed out, from the exterior to the interior. The upper surface first freezes, and the thickness of the solid layer afterwards increases from top to bottom. Physicists were of opinion that such was the case also with running waters, at the bottom of which the formation of ice seemed to them impossible. Yet this last opinion was very popular: millers, fishermen, boatmen, maintained that the floating ice with which the rivers are frequently obstructed in winter invariably rose from the bottom; and the German sailors even invented a special and characteristic name for it, *grundeis*, that is bottom ice, or ground ice.

When the question was examined anew, our philosophers discovered that the phenomenon which had appeared so contrary to the laws of the propagation of heat was very real, and that the opinion they had so long regarded as a prejudice must be admitted as a truth.

Braun, a German naturalist, published in 1788 the following observations, which he had collected among the fishermen of the Elbe:—

"During the cold days of autumn, long before the appearance of ice on the surface of the river, their nets,

lying at the bottom of the water, grow covered with such a quantity of ice that it is very difficult to haul them up; the baskets which they use for catching eels frequently rise to the surface, of their own accord, incrusted externally with ice; anchors lost in summer are frequently regained in winter, being brought up by the ascensional force of the ground ice with which they are coated; this ice also raises the heavy stones to which the buoys are fastened by mooring-chains, and thus occasions the most troublesome displacements of those useful signals."

Arago, in his paper On Ice,* sums up concisely the results of the remarkable observation made by Mr. Knight upon a Herefordshire river, one morning after a night of extreme cold:—

"The river, pent up by a dam, forms a large basin of tranquil water used for turning the wheels of a large mill. The water falls through a sluice into a narrow canal, impeded here and there by rocky projections and large stones, which produce a succession of eddies and whirlpools. The river is shallow, and flows over a pebbly bed. On the surface of the stagnant water of the upper basin the eye discovered thousands of tiny floating icicles. Lower down, after the fall into the river properly so called, the stones at the bottom were covered with a shining substance, of silvery brightness, which, when closely examined, proved to be an aggregation of ice-needles crossing each other at all kinds of angles, as in snow. On each stone this substance or fibrous ice was deposited in the greatest abundance along the sides

* "Annuaire du Bureau des Longitudes," 1833.

lying opposite to the current. It had not the consistency of the ordinary compact ice found close to the river-banks."

Hugi, the Swiss geologist, saw the development of ground ice on a large scale in the river Aar, at Soleure. The river, in 1827, at the beginning of February had overflowed; but on the 15th it had completely subsided, and its waters had recovered their purity. Finding himself at a distance of about seventy-five feet below the bridge, Hugi ascertained that over an area of about one hundred and seventy square yards a multitude of ice-tables rose continually from the bottom of the river. These icebergs mounted vertically until they were about three feet above the surface; then they fell over, and floated horizontally. After a certain time they became fewer, but of greater dimensions. Several, at the moment of assuming a vertical position, still rested by one of their sides on the river-bed, and were held in this way for some time. The same phenomenon occurred in 1829, and likewise in the month of February. Indeed, on this occasion Hugi saw actual islands of ice formed in the middle of the river. One day he counted twenty-three, of which the largest was nearly thirty-five yards broad. They floated in open water, resisted the stress of a rapid current, and extended over an area of about five hundred square yards. He ascertained, by personal examination, that on the surface they were composed of a compact ice, from two to four inches thick, resting on a mass, shaped like a reversed cone, of ten to fifteen feet in height, which was attached at the bottom to the river-

bed. All the cones were composed of a half-melted and almost gelatinous ice, easily penetrated by poles, and reduced to grains when exposed to the free air.

An explanation of these singular phenomena has naturally been sought for. That which Arago has put forward is not complete, as he himself confesses, but the principal points are sufficiently clear. He remarks, in the first place, that the mechanical action of running water originates a circulation, which leads to the entire mass of the liquid being equally mixed and cooled. It is afterwards brought uniformly to the temperature of zero: but why, then, does the congelation take place at the bottom and not on the surface?

Who does not know, replies Arago, that to hasten the formation of crystals in a saline solution it suffices to introduce into it a sharp-pointed body or an unequal surface? That it is around the asperities of this body the crystals principally originate, and receive rapid augmentation? Everybody can satisfy themselves that it is the same with ice-crystals; that if the vessel in which the congelation is to take place presents a fissure, an angle, a solution of continuity, that fissure, that angle, that solution of continuity will become so many centres round which the solidified filaments of water will group themselves in preference. And this is precisely the history of the congelation of rivers, which takes place only on a river-bed strewn with rocks, or stones, or pieces of timber, or vegetation.

In the second place, continues Arago, the movement of the surface water being always very swift and abrupt, necessarily prevents that symmetrical grouping

of the icicles, that arrangement, without which the crystals, of whatever nature they are, can acquire neither regularity of form nor solidity. But, on the contrary, the ground movement is very feeble, and we may suppose that its action will suffice only to impede the formation of a compact or regular ice, and not prevent in the long run the formation of a multitude of minute filaments adhering to one another confusedly, and in such a manner as to engender a fibrous ice.

Cases, however, occur in which even a hard and compact ice is formed at the bottom of water-courses. A French writer gives the following example :—

Some years ago, he says, on a beautiful day, I went alone, and on foot, from Barême to Digne, following a path along the right bank of the Asse, where since a road has been constructed. The old road passed, without any bridge, across several torrents, which were dry for three-quarters of the year. But on this occasion I found it blocked up by the torrent of Novante, with a breadth of fifteen to eighteen yards, and I had to take off my boots and ford it. As soon as I entered the water, I found myself treading on a smooth hard ice, the existence of which I had not even suspected, and the incline at the bottom made me slip into the middle of the torrent, where I was able to stand upright. Afterwards, when I began to move towards the other bank, the transversal slope, rising upwards, made me glide backward. And in order to advance at all, I was compelled to let my feet rest naked on the ice until they were slightly incrusted by the effect of the vital heat.*

* Breton, "L'Ami des Sciences," année 1861.

Why was the ground ice in this rapid torrent so hard, compact, and polished, while that which forms in the slow-moving rivers is always soft, fibrous, and rugged?

According to M. Breton, the difference may be thus explained :—

"The ice at the bottom is formed through icicles or their crystalline plates, implanted on the little rugosities of the soil; if one of these fragments of ice is directed square to the current—or, still better, if it is obliquely inclined up the river—the current has a strong holdfast to whirl it round in the opposite direction, and lay it flat on the bottom, or rather on layers of ice already formed. Consequently, when this current is rapid, all the laminæ are brought close together, and not an interstice remains between them filled with water still in a liquid state. If a thin icicle is constructed on the summit of a projection, it penetrates into the liquid threads which are strong enough to dissolve it gradually away; which is not the case in the more concave portions of the solid wall, where the ice can therefore increase more promptly. Hence results the perfect smoothness which we notice. On the contrary, in a slowly-flowing river the current has not force enough to level in a downward direction the acicular or lamellary crystals of ice as fast as they are created at the bottom; thus they preserve their varied directions; then they cross one another, and imprison between them the water at 0°, which, when once it is thus confined, is no longer renewed, but long remains liquid.

SURFACE ICE.

We have just been examining the ice formed at the

bottom of running waters while the general mass still remains liquid. But the surface also congeals very quickly when the cold increases there, and especially when the prevalence of clear open skies permits of an abundant nocturnal radiation.

River-water first begins to freeze along the banks; the two lateral belts afterwards enlarge progressively, and eventually meet together. The superficial congelation depends greatly on the depth and swiftness of the stream. In proof, too, of the manner in which this phenomenon is affected by certain meteorological conditions, Arago quotes an instance that seemed to him a very singular anomaly.

In December 1762, the Seine was completely frozen at the end of six days of frost the mean temperature of which was —3° 9, and when the minimum temperature had not exceeded —9° 7; while in 1748 it continued to flow after eight days with a mean temperature of —4° 5, the greatest cold rising as high as —12°. Yet at both epochs the depth of the water was the same; but in 1762 the six days which preceded the total congelation were perfectly serene, while in 1748 the sky was cloudy or wholly obscured. To remove the contradiction between these observations, we must add 10° or 12° as the effect of the radiation of the water towards space, to the cold indicated by the thermometer in 1762. The same cause may explain how, in the extremely severe frosts which reigned at Paris in 1709, and during which the temperature descended as low as —23°, the Seine in its centre remained constantly fluid.

Sometimes the ground ice exists simultaneously with

the surface ice, as Hales ascertained by his observations of the Thames. He remarked that the two strata united against the bank, but that they receded further and further from one another as, advancing into the river, the depth of the water increased.

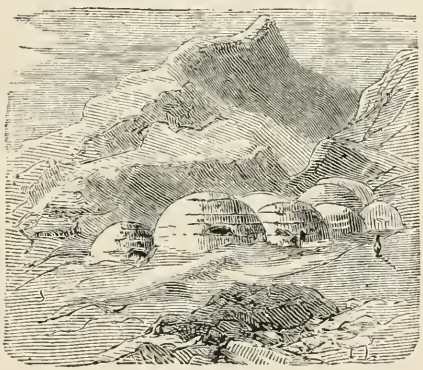
Some curious details of this twofold congelation may be found in a paper by Fournet, president of the Hydrometric Commission of Lyons :—

"During the severe winter of the last months of 1788 and the first months of 1789, the Engineer of Mines, M. de Rozières, observed that the Rhone began to fill with drift ice at Valence on the 27th of December, and that it was frozen from the 29th of December to the 13th of January. We could thus cross the river for sixteen days successively, a circumstance unknown in the memory of the oldest inhabitant. Moreover, experiment showed that the river was frozen from its surface to its bed; in several places, so much of its water as remained liquid flowed between piles or pilasters of ground ice, which supported the superficial crust, as if it had been a roof. I have met with a similar occurrence in the bed of the glacial spring whose waters cover all the soil of the cavern of Brudoure, in the Vercors. There I walked along the tops of stalactites, placed in the inverse direction of the ordinary position of these concretions, and the water flowed in the spaces between them; nothing was wanting but an upper crust which might have served me for a flooring."

The overflow and descent of fluvial ice frequently causes great disasters. In their rapidity of movement, these

masses shatter and carry away bridges, overthrow houses and public buildings, and, by choking up the narrower passes, give rise to terrible inundations.

Ice has occasionally served, and still serves, for the construction of singular edifices. During the winter of 1740, a palace was erected at St. Petersburg with great blocks of ice from the Neva, some of which measured 52 feet in length by 20 feet in height. Four blocks were also fashioned into the shape of guns, and these ice ordnance discharged iron shot without cracking or melting.



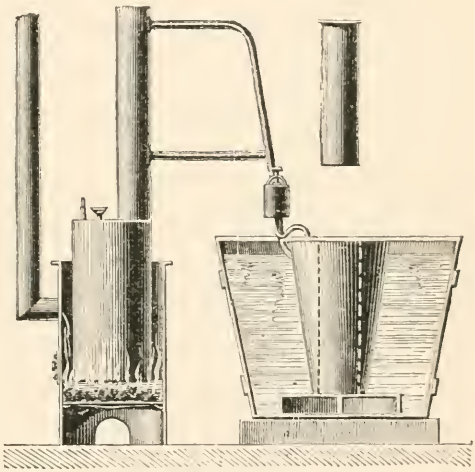
ESKIMO HUTS.

The Eskimos pass the winter in huts made of blocks of hardened snow. These huts resemble circular domes, with a diameter slightly exceeding ten feet. A single day is generally long enough for their erection.

Note also that bi-convex lenses have been manufactured out of ice by the philosophers. Like those of crystal, they concentrate the solar rays, and ignite the combustible materials exposed to their focus. Finally, in very cold countries—as, for example, in Siberia—panes of ice are frequently used in windows instead of glass.

Ice is now-a-days employed to prevent or arrest fermentation, or to induce crystallizations, as was recently done with the view of extracting the salt called sulphate

of soda from the head-waters of the salterns of the Camargue. Ice artificially manufactured is also employed in utilizing the property of liquids to transform themselves into gas at the expense of the heat of surrounding bodies. The ingenious apparatus invented by M. Carré is founded on this principle. The only expenditure required is that of a small quantity of fuel. We may therefore hope for a very great extension of this new process, and the far more general employment of ice, both as an industrial agent, and as an object of consumption.



CARRÉ'S FREEZING APPARATUS.

In medicine, ice is esteemed a valuable styptic, and it has also been recommended by Dr. Chapman for external application in cases of cholera. In certain forms of paralysis and spino-cerebral disease it is also useful as a therapeutic.

ICE-TRADE OF THE UNITED STATES.

The Americans of the Northern States long ago perceived the advantages to be derived from the use of ice in the daily necessities of life, and as early as 1792 the Maryland farmers were in the habit of constructing small ice-houses for the preservation of their principal alimen-

tary supplies. From this epoch the employment of ice spread rapidly into all the great centres of population of the Northern and Middle States. Vast establishments were erected to receive the annual stores; and in 1805 a merchant of Boston, Mr. Frederick Tudor, undertook to export some cargoes of ice to the intertropical countries. His first attempts were restricted by the Great War, which reduced the field of his enterprise to Martinico and Jamaica. On the return of peace, in 1815, he extended it to Havannah, Cuba, and New Orleans; and in 1833 despatched an expedition to Calcutta, and thence to Madras and Bombay. The trade has now-a-days assumed considerable proportions; numerous companies, and a large number of ships, are engaged in the exportation of ice. At Calcutta it is stored in an immense building, erected on purpose, from which it is sold to retail dealers. This singular magazine has three walls, and five distinct roofs; it covers about thirty acres, and can contain upwards of 30,000 tons of ice. Since 1852 the commerce has assumed an enormous development, and extended to China, South America, Australia, and Europe, where London has become an important outlet for American ice. In 1859 the total amount exported was 129,403 tons.

The ice exported from America is principally drawn from different lakes situated on an elevated table-land about eighteen miles from Boston, whither it is transported by railway. The collection of the ice is made in December and January. At that epoch it is possible to calculate the probable yield of the lakes or ponds. The men engaged in this branch of industry do not need,

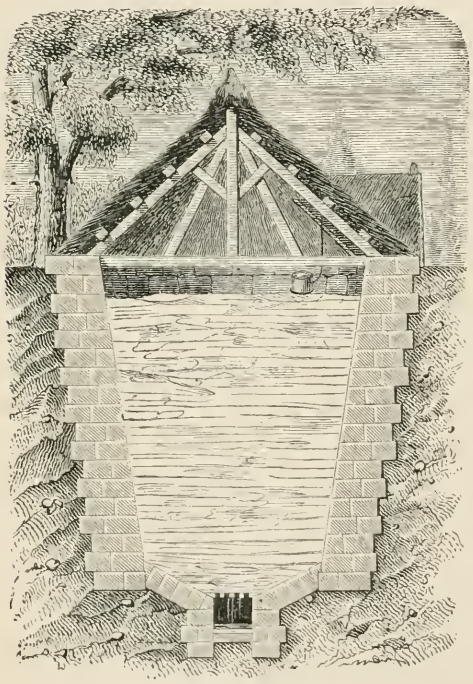
like agriculturists, to sow that they may reap; they have only to wait patiently the travail of Nature—which, however, they sometimes assist, by making openings in the frozen surface of the lakes, so that the water may overspread it, and thus the thickness of the ice be increased. They also remove the snow from time to time, because it is injurious. Apart from these preparatory labours, they have nothing to do but bide the time for reaping their icy harvest.

When the ice is in a suitable condition for cutting,—that is, when it is nine or twenty inches thick, according as it is intended for home consumption or exportation,—the proprietor of the lake first orders the stratum of snow to be removed with a wooden machine drawn by a horse. This operation ended, the frozen snow, from which no profit can be derived, is hewn or chiselled off by a machine of iron, armed with a cutting instrument of tempered steel. This machine, a kind of scraper, clears away the frozen snow for several inches in depth.

The third operation consists in dividing the ice into blocks of four to five feet square, by means of a keen instrument inserted in a framework drawn by a horse, and manœuvred something like a plough. Then, in the furrows which it traces, they work another instrument adapted to a machine likewise drawn by horses: it cuts into the ice deeply, but not so as to divide it entirely; nothing remains but to separate the blocks with a handsaw, so that they may float freely in canals hollowed in the surface of the lake, and arranged so as to bring the crop to shore.

From the shore the ice is transported in carts, or,

which is preferable, it is placed block upon block on an inclined plane, and propelled by a steam machine up to a certain elevation. Thence it is guided by a man's arm to the door of the ice-house, by a plane inclined in a contrary direction to the former, and at a low abrupt angle. A steam machine is also used to stow the blocks in the ice-house; and this part of the work can be done as well by night as by day, if the weather permits.

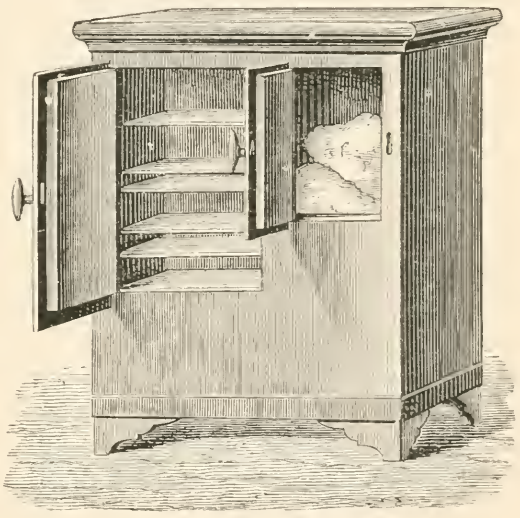


AN ICE-HOUSE.

The quantity of ice which the ice-houses of Boston can receive is estimated at 300,000 tons. In the neighbourhood of New York about 280,000 to 300,000 tons are gathered yearly, almost the whole of which is consumed by the city and the neighbouring localities.

The reader will remember the story of the antediluvian mammoth which was discovered through a landslip on the bank of the Lena, and whose body, embedded in the ice, was in a condition of admirable preservation. The bears immediately set to work to devour this flesh contemporary

with the Deluge, and the naturalists, informed by the Yakout hunters of what was going on, were in time only to collect what had escaped the voracity of these carnivora. This property of ice, to preserve organized bodies from corruption, has long been known to the inhabitants of the Polar Zone; and the Americans, by thus utilizing ice as an ordinary means of preserving food, have made it a common article of consumption, the importance of which daily increases. There have been produced in the United States a host of refrigerating apparatus of all models and all dimensions. The one generally used in families may thus be described: It consists of a kind of rectangular chest, with wooden sides three inches thick, which are lined internally with double plates of zinc. This refrigerator is generally divided into two compartments: the one for the supply of ice, and the other for the storage of food during the summer heats. Were the ice brought into direct contact with such provisions as milk, butter, meat, fish, it would absorb something of their savour, especially if fusion had



REFRIGERATING APPARATUS.

commenced; but this inconvenience is obviated by submitting them only to the cold which it produces.

An enormous quantity of ice is employed in the markets to preserve the fish, shell-fish, and molluscs intended for the consumption of the sea-side population, or to assist the despatch of provisions to the interior. On board the American fishing-boats this process, adopted some centuries ago by the Chinese, and, in Europe, by the Sardinian, Tuscan, and Neapolitan fishermen, has led to most important results. Suffice it to say that the American fishermen forward their cargoes to market in a state of perfect preservation, though they may have had them on board for ten days. What with well-boats, and boats with ice-cellars, and boats provided both with wells and ice-cellars, cargoes of fresh fish, shell-fish, and crustaceans, all alive, are brought into port, and sold at moderate prices. The employment of ice, it has justly been remarked, has thus produced a revolution in the public alimentation, and helped to solve the important problem of cheap living.

Within the last few years, Norway, following in the path of the United States, has exported cargoes of ice to various European countries, and we may certainly draw from this source a supply at moderate rates which will put within our reach the preserving processes so successfully employed in America. But we ought to remember that this result is not due only to ingenious processes and favourable geographical conditions. It also depends on the habits and character of the populations which profit by it:—

The habit and love of work constitute the distinctive characteristic of the American people, and all their faculties are directed towards useful and practical knowledge. They pay but little attention to the imaginary or ideal; and have laid it down as a primary necessity —encouraged in this, undoubtedly, by the legislators and best intellects of their country—that an easy subsistence must be insured to the masses. Of this fact you may convince yourself by observing the convergence towards the States of food-supplies at such low prices, compared with the high standard of wages, that game and venison, fish, meat, vegetables—in fact, everything which constitutes the luxury of the table—are brought within the reach of the greater portion of the population. The railroads contribute powerfully to this issue, their companies having the good sense to perceive that, while paying proper attention to the interest of their shareholders, they are bound to fulfil towards the nation an imperative duty,—that of facilitating the provisioning of the towns by the adoption of moderate tariffs. So far as the fishing industry is specially concerned, the United States can despatch into the interior, with great swiftness, their molluscs and fresh fish, without paying such heavy prices for their transport as will absorb to a great extent the fishermen's profits, and raise the cost of their products. Do not forget that the moral value of a people, and the dignity of their character, are the consequences of cheap living, which alone can protect them from the debasing influences of poverty. For, as Michelet says, the pauper is a slave.

II.

The Glaciers.

"And the slow glacier down the mountain-flank
Creeps with an unseen motion through the ages."

LAW OF CIRCULATION.

BETWEEN the snows which every winter fall in the lofty regions of the globe, and those which every summer disappear there, the compensation is not perfect, and a residuum constantly remains. It is only beneath the boundary known as the line of perpetual snow, that the snow which descends each winter season is wholly melted when the "bright days" come. But if the annual excess which loads every mountain accumulated on its summit for any lengthened period, we should surely see in all highland regions immense strata of ice rising to the extreme elevation which the aqueous meteors attain in the terrestrial atmosphere.

And in this way one of our most mobile elements would be retained in an everlasting captivity.

It is very evident, however, that nothing of this kind takes place, or has taken place, in nature. "The economy of the world," says Rendu, "would be soon destroyed, if

accumulations of matter could take place upon particular points. The centre of gravity of our globe would be insensibly displaced, and chaotic confusion would succeed to the present admirable regularity of its movements. If the Poles did not return to the Equatorial Seas the waters which, reduced into vapour, issue daily from these burning regions to be converted into ice at the two extremities of the globe, ocean would be exhausted, and with the cessation of water life too would cease to circulate over the earth. The conservating will of the Creator has employed, to insure the permanency of His work, the vast and powerful law of circulation, which, upon close examination, we find reproduced in every part of nature. Water circulates from the ocean into the atmosphere, from the atmosphere descends to earth, and from earth flows into the seas. The rivers return whence they issued, so that they may flow again, says Holy Writ; the air circulates around the globe, and, as it were, upon itself, passing and repassing successively through all the heights of the atmospheric column. The elements of organic substance circulate in their transition from the solid state to the liquid or aëriform state, and from the latter to the condition of solidity or organization. That universal agent which we variously designate fire, light, electricity, and magnetism, has probably also a circle of *circulation* as extensive as the universe. If any day its movement should be better known to us, it would perhaps afford us the solution of a host of problems which still weigh upon the human mind. Brought back from each portion of the great whole, circulation is still the law of life, the mode of action employed by Providence in the administra-

tion of the universe. In the insect, as in the plant and as in the human body, there exists a circulation; or, more correctly speaking, several circulations exist—of blood, of humours, of elements, of fire, and of everything which enters into the composition of the individual." *

This great law of Nature the glaciers must also obey. As a means of clearing the higher regions of our earth, we must consider the descent of avalanches,—that is, of masses of snow and ice which detach themselves from the abrupt declivities, and sweep headlong, in ruin and confusion, to the mountain-base, where the warmer air rapidly reduces them to a state of fusion. But this phenomenon, the cause of so many terrible catastrophes, does not give rise to any great transportation of matters compared with the residuum annually deposited by the so-called glacier-reservoirs. Another movement takes place, at once more efficacious and more regular, embracing the whole system of the ices, and determining the formation of glaciers *d'écoulement* (drainage-glaciers) which issue from the reservoirs to descend far below the line of perpetual snow into temperate regions, where a dense stratum is melted every year at their lower extremity. This general progression is one of the most fertile discoveries with which the science of terrestrial physics has recently been enriched. Numerous naturalists and physicists have made it the great end of their researches, and in those researches have displayed no less courage than intelligence. They may be considered to

* Rendu, "Théorie des Glaciers de la Savoie."

MONT BLANC—SEEN FROM THE JURA.

date from the gallant excursions and memorable sojourns among the glaciers of Switzerland of Messrs. de Charpentier, Agassiz, Desor, Vogt, James Forbes, Bravais, Charles Martins, Dollfus-Ausset, Hopkins, Tyndall, Collomb, John Ball, Schlagintweit, and others. We are now about to follow these pioneers of science into the heart of the Alpine solitudes, summing up the principal observations and data which serve as the foundation of the theory now generally adopted.

PROGRESSION OF THE GLACIERS.

The chain of the High Alps presents from a distance the most beautiful of spectacles. On sunny days the clouds which crown its peaks are of a dazzling whiteness; but it is especially at evening, at sunset, that it should be contemplated, when the far-off summits, blushing with a roseate glow, stand out in sharp bold outline against the intense azure of the heavens.

In climbing the acclivities of these mountains to gain their magnificent domes, the traveller wanders long in the midst of cultivated fields, forests, and meadows. At a great elevation he still finds himself surrounded by villages, with their smiling gardens and luxuriant vineyards. But all at once he is struck with a keen surprise to see a white hill starting up before him in the centre of all this prodigal vegetation. This hill is the extremity of a glacier, which it is by no means unusual to find in the immediate vicinity of corn-fields completely ripe. On an excursion among the Bernese Alps, it happened to ourselves to pluck some fruit from a wild cherry-tree growing by the side of the Grindelwald glacier, of which

the lower extremity is visible a few minutes after you have quitted the village of that name.

GLACIER OF GRINDELWALD.

The presence of so huge a mass of ice at a point where the snow disappears in the month of April, or early in

May, was long regarded as an inexplicable phenomenon, until suddenly the idea occurred to some ingenious minds that the glaciers, perhaps, were animated by a slow movement. At the date of our journey, the various questions connected with this mysterious progression were ardently discussed among the adventurous explorers whom we saw depart, with numerous instruments, to execute, in the icy solitudes of the upper regions, those delicate measurements which might afford a basis for future theories.

Before we submit to the reader a summary of what has been accomplished in this part of the Alps, we must direct his attention to the data collected by Monsignor Rendu, in his great field of research, Mont Blanc; where he devoted himself, with assiduous enthusiasm, to a careful examination, along their entire course, of what, by a very remarkable intuition of the truth, he called the *rivers of ice.*

Pausing upon their summits, he saw them bristling with pinnacles and ridges of granite, which held together the ice, and prevented it from being evenly distributed over every side of the mountain. But in among these obstacles opened various valleys, serving as canals for the escape of the ice; and these canals, uniting together, one by one, as they descended towards the lower levels, enabled the *tributary glaciers*—to use the technical language — to coalesce in one great *trunk-glacier.*

Everywhere the mass of each glacier appeared to be in an inverse ratio to the incline upon which it had accumulated. Where the descent was rapid, the ice was thin, and its surface contracted; where the inclination was gentle, the glacier expanded like a lake.

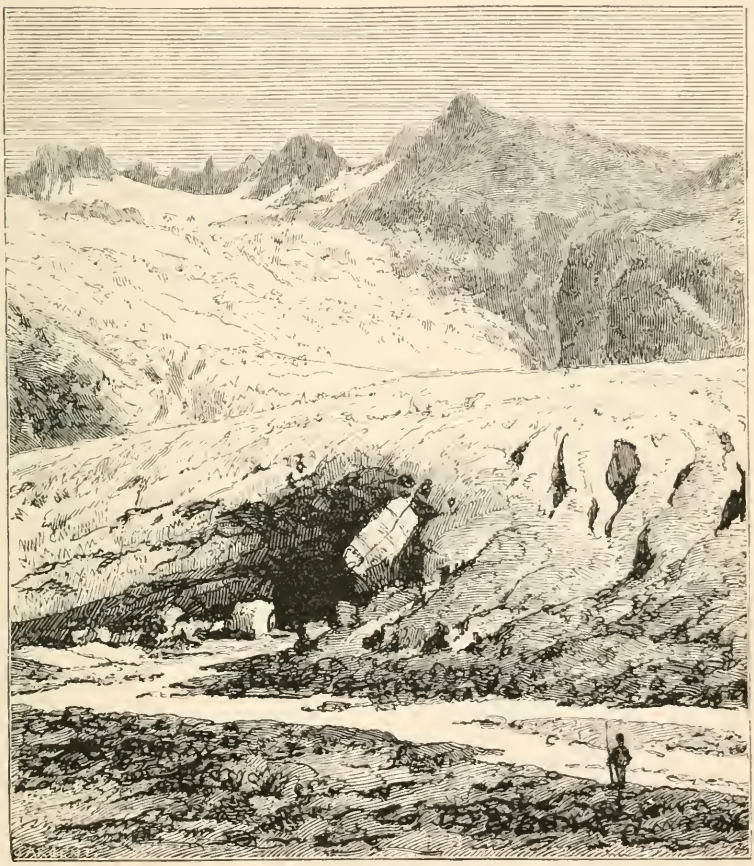
A description drawn up by the first and most illustrious explorer of Mont Blanc, M. de Saussure, shows very clearly that the glaciers mould or adapt themselves to the configuration of the ground which supports them. "The glacier of Mont Dolent," he says, "has for its upper table-land a great circus surrounded by pyramidal blocks of granite; thence the glacier descends through a narrow gorge in which it has been closely confined; but as soon as it has passed this ravine, it enlarges anew, and opens wide like a fan. Its outline, therefore, is exactly that of a sheaf,—contracted in the middle, and detached at either extremity."

Wherever a glacier terminates, the most manifest signs may be found of its successive destruction under the influence of the solar heat. This fountain feeds the great rivers, such as the Rhine, the Rhone, the Aar. Often their source is seen to escape from the vast caverns which the waters, conjointly with atmospheric agents, excavate in the glacier; caverns which crumble in when the height and extent of their icy roof overpasses the limit of the resistance of the materials. We shall describe by-and-by one of these caverns, which present, when you penetrate their interior, the most marvellous aspect, through the play of light decomposed in the walls of ice as in a prism.

But we have still more evident proofs of the progressive movement of the glaciers.

At the lower extremity of the Grindelwald glacier we have seen great blocks of granite deposited on a soil of wholly different character. To discover whence they had come, we had to ascend as far as the *névés*. There, in the upper part of its long valley, the glacier had received them

as they fell from the lofty peaks dominating over it, and it was clearly by its own movement they had been transported to the point where, in dissolving, it had abandoned

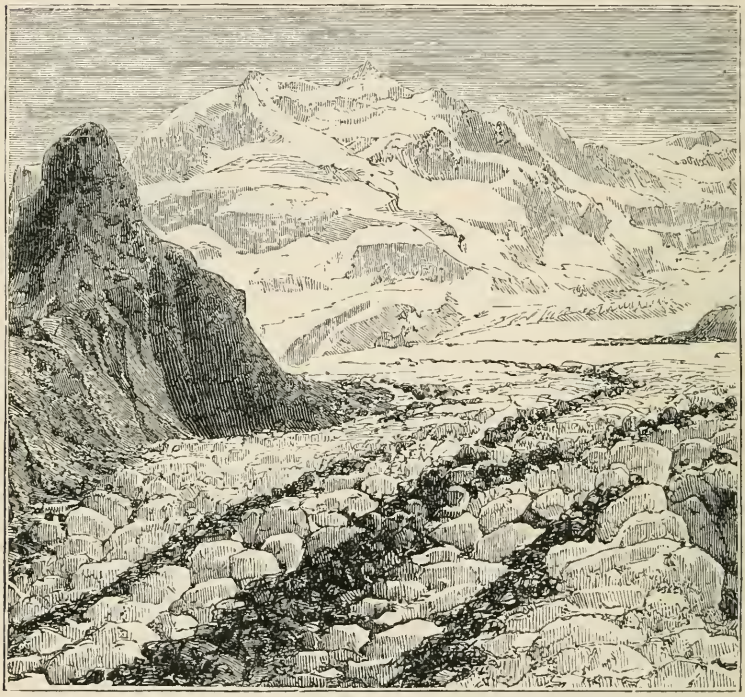


SOURCE OF THE RHONE.

them. To demonstrate with more exactness the descent of the rocks towards the valley, and, consequently, the movement of the glaciers, it has been found sufficient to lay down certain lines by means of fixed points, such as

trees, or remarkable spots on the side of a mountain, and to repeat the operation from year to year.

The accumulation of these débris forms on the surface of the glacier certain long ridges of blocks and stones which are known by the name of *moraines*, and which



MEDIAL MORAINE OF THE GLACIERS OF MONTE ROSA.

run in different directions according to circumstances we are about to explain.

The landslips occurring along the edges of a glacier produce *lateral moraines*, which daily increase and extend, through the twofold effect of the descent of the blocks, and the movement of progression which carries them

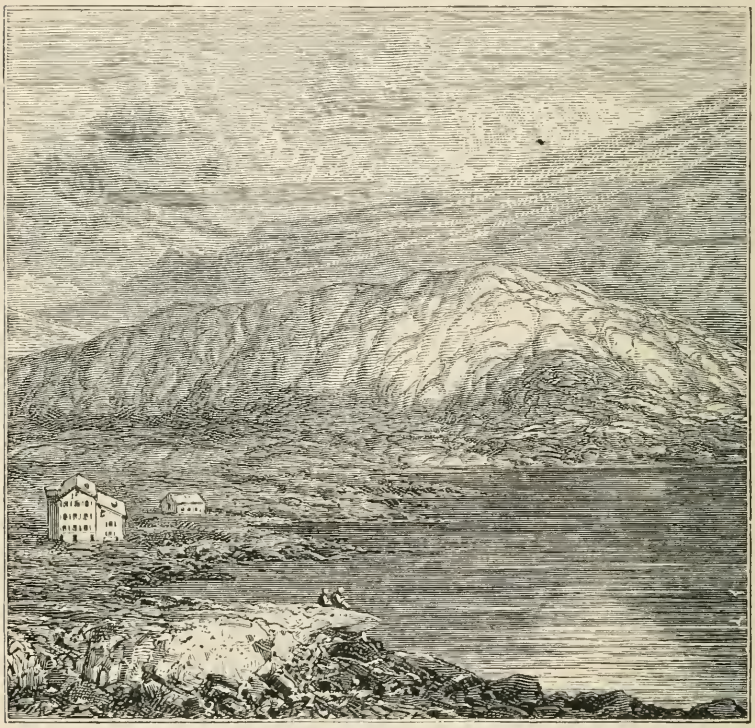
downward along with the entire mass of ice. Towards the centre of the great glaciers nearly always exists a *medial moraine*, resulting from the junction of the lateral moraines of two glaciers which have united into one. These superficial moraines sharing in the glacier-movement, their boulders and débris eventually roll to the foot of the escarpment which terminates it, and a *frontal moraine* is

FRONTAL MORAINE OF THE GLACIER OF THE OBEI-AAR.

thus created on the very soil of the valley, like a barrier in front of the last ice. Finally, the stratum of sand and fragments lying underneath the glacier, and upon which it glides, has been designated the *moraine profonde*.

The striations produced by this last-named stratum on the bed of the channels in which the glaciers flow, bear witness to the great power of friction they exercise during their progression. The depth of the striations depends

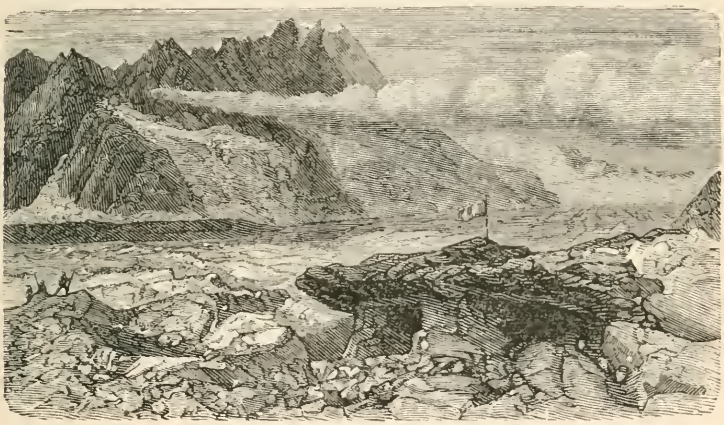
evidently on the hardness of the débris carried down by the glacier, and the nature of the rocks subjected to the friction. The polished aspect of the rocks, when they possess sufficient solidity to resist the march of the glacier, indicates the enormous pressure it exercises on the



ROCHES MOUTONNÉES.

slopes of the valleys whose ruggednesses it wears down or destroys. This effort, bearing principally upon the side of the rocks turned towards the summits, impresses upon them a peculiar rounded form, not unlike the appearance of a flock of sheep; whence Saussure christened them *roches moutonnées.*

In 1840, the glacier of the Aar still exhibited the traces of a small stone cabin, the displacement of which had greatly contributed to illustrate the movement of the glaciers. It had been constructed in 1827 by the geologist Hugi, one of the most active of Alpine explorers, at the point where the glacier doubles round a mountainous promontory named the Abschwung. Three years later it was found 100 mètres lower down, and in 1832 had descended 715 mètres.* In 1840, a few ruins were still



HÔTEL DES NEUCHATELOIS.

extant, but were situated at a distance of 1495 mètres from the Abschwung. That it was the same cabin was proved by a bottle found under a cairn of stones, which Hugi had deposited there, with a note of his observations. Consequently, in a single year it had accomplished a journey of about 115 mètres.

The station where an illustrious glacialist, M. Agassiz, in conjunction with several friends,—Messrs. Dessor, Vogt,

* A mètre is 39.370 inches. 304 mètres = 1000 feet.

Nicholson, and others,—studied the same phenomenon, has acquired a lasting celebrity under the name of the *Hôtel des Neuchâtelois*. It was situated on the glacier of the Aar, at an elevation of 650 mètres above the Abschwung, and was found to move downward at an average rate of 75 mètres per annum. A great block of ice served as the roof; the kitchen and sleeping-apartment were also built up with ice. A stone bench covered with hay served as

PAVILION OF THE GLACIER OF THE AAR.

a bed for the courageous *savants* during their voluntary exile.

Recognizing the necessity of securing a more convenient shelter, for the sake of the observations which he contemplated making, another eminent observer, M. Dollfus-Ausset, caused to be erected, in 1842, on the south side of the glacier, a pavilion, in which several chambers were always at the disposal of men of science and travellers. Thanks to this generous solicitude, we may now study the phenomena of the glaciers without exposing ourselves to

the great privations endured by the first pioneers in these desolate regions.

Of late, M. Agassiz has continued in North America the labours which have rendered his name so justly celebrated; and among these labours, those relating to the study of the ancient glaciers of the New Continent have confirmed the discoveries due to the observation of the same phenomena upon the chain of the Alps and the secondary chains of Europe.

ANALOGY BETWEEN GLACIERS AND RIVERS.

As soon as the descent of glaciers along their valleys had been ascertained to be a fact beyond doubt, naturalists set to work to measure with the utmost carefulness and exactitude the movements of their different parts, which they found to be very different. They employed the following process: A series of poles or posts was planted in a straight line, and each row was referred to certain distinct marks on the sides of the lateral rocks. In the following year, on visiting these posts it was discovered that they had moved forward, but were no longer situated in a right line. They had described a curve, which, by its inflections, indicated the relative progress of divers points of the surface.

It was in this manner M. Agassiz discovered that the centre of the glacier of the Aar advances annually about eighty yards, while the lateral portions are not displaced by more than a score of feet. Similar measurements made upon numerous other glaciers prove that this motion may be considered as a general law; a law which is also established by the inspection of every transversal crevasse.

These crevasses, in fact, never preserve a straight line, but gradually assume a curvilinear form, which in its convexity advances towards the bottom of the valley.

It has also been ascertained that the superficial part of the glaciers moves more quickly than the undermost. And Tyndall and Hirst have demonstrated, with the help of instruments of very great precision, that the maximum of velocity is not to be found always in the centre, but that, according to the sinuosities of the valley traversed by the glacier, it passes sometimes to one side of the centre and sometimes to another. Now, the motion of a river presents exactly all the characteristics we have just enumerated, and the truth anticipated by Rendu has been demonstrated to its smallest details. When, for example, standing on a bridge, we watch in what manner a river strikes against the piers, we see that the water rises in front, sweeps round the obstacle, and then eddies backward. The same effect is plainly discernible in the neighbourhood of the promontory of Trélaporte, or the Mer de Glace of Mont Blanc, where, indeed, it is displayed on a colossal scale.

But how is it that a substance apparently so rigid as ice can in this way yield obedience to the laws of the movement of fluids?

This question presented itself to the men of science who were unable to agree with M. de Saussure that glaciers simply glided down the declivities on which they had first accumulated.

The physicist Scheuchzer attempted to explain it by referring to the infiltrations of water into the numerous fissures of the ice. He asserted that the whole mass might be compared, during summer, to a sponge filled

with water, which, congealing afterwards through the cold of autumn and winter, expanded, and produced a dilatation of the glacier in all directions. As, however, it could not reascend the slope, its augmentation of size took place at the lower extremity. This theory, which was likewise adopted by M. Agassiz, could not stand the test of later observations. Our English physicist, Forbes, next developed his ingenious conceptions of the viscosity of ice; but these, in their turn, have been generally rejected, since Professor Tyndall has demonstrated that the regelation, of which we have spoken in the preceding chapter, can best explain all the circumstances of the phenomenon.

It has been proved, by lowering thermometrographs into the vertical pits or wells of glaciers, that the latter permanently preserve, in all their parts, the temperature of 32° or thereabouts, necessary for the operation of regelation. Owing to the great pressure it experiences, the ice is pounded, the internal contact is every moment broken up; but the innumerable surfaces thus laid bare soon unite again, for, to the beginning of the fusion excited by the pressure corresponds a cooling of the adjacent portions of ice,—a cooling which, in its turn, produces regelation.

This molecular action is sufficient to adapt the ice to the sinuosities of its channel, while constantly remaining a compact whole; but at certain points, owing to an abrupt change of slope, or the movement of the mass around a promontory, the fissures produced can no longer close up again, and great *crevasses* then yawn wide across the surface of the glaciers. The formation of these "chinks and crannies" is in direct opposition to the theory which would assimilate a glacier to a viscous body: if such a

body winds round a promontory, it delays its march, but no solution of continuity occurs in its mass; if it arrives at a bolder incline, its progress is accelerated without any disruptions taking place.

But, on the contrary, very considerable dislocations are found in glaciers at those points where the bottom of the valley suddenly changes its inclination. In precipitating themselves over the steep descents they form *cascades of ice.* Professor Tyndall speaks of a spectacle which he saw on the glacier of Talèfre, before its junction with the Mer de Glace of Mont Blanc. At the spot, he says,* where the fall commences, enormous transversal crevasses have been produced, and these soon succeed one another so rapidly as to reduce the entire mass of the glacier to an aggregate of angles and disjointed blocks, which the traveller crosses with incredible difficulty, and only by crawling on his hands and knees. Sometimes these blocks and wedges are curved and bent by the action of the lateral pressures; and rotatory forces have so acted upon certain points that they have whirled round great pyramidal masses some 90°, and brought into right angles with one another surfaces which, in their normal position, were contiguous. Afterwards the ice begins to fall, and the portions exposed to view become a fantastic assemblage of fragments, pinnacles, and turrets, sometimes erect, sometimes overthrown, shattered at intervals by the reverberation of the mountain thunder, and reducing into fine dust the rocks of ice on which they headlong crash.

Similar cascades may be seen on the glacier of Corbas-

* Professor Tyndall, "Heat Considered as a Mode of Motion."

sière, on the Glacier des Bois, and below Montanvert, on the Glacier du Géant, between the Aiguille Noire and that of Blaitière, on that of the Lower Grindelwald, below the Stiegg. After the glacier has crossed the *dénivellation*, the cascade ceases, the crevasses become fewer in number, and a smooth continuous surface is reformed, which the explorer may easily traverse. It is evidently owing to a successive regelation that, on a gentler incline, all the parts composing these cascades of ice are once more soldered together.

CASCADE OF THE GLACIER OF CORBASSIÈRE.

USEFULNESS OF GLACIERS.

The Intelligence ever conspicuous in the works of Nature has stamped its seal on the glaciers no less unmistakably than on the fertile plains, loaded with golden harvests. All the earth has been so ordered in its movements and its forms as to preserve and reproduce the life first breathed into it by the Divine Power. Fire, air, and water are for all organized beings the primary condition of life; and the wonderful combination by which they are ever prepared to meet the wants which are ever arising, reflects the Divine thought on the created thought. The fire which accompanies the orb of day, the fire which descends upon the earth, reascends towards the stars, and again descends to us; air, which consumes itself, is ab-

sorbed and recomposed; water, which incessantly flows round the earth, what is it but the flux and reflux of life? "Bless the Lord, all his works, in all places of his dominions.....O Lord my God, thou art very great; who laid the foundations of the earth, that it should not be removed for ever. Thou coveredst it with the deep as with a garment; the waters stood above the mountains."

If the waters which the rains and the condensed vapours pour upon the earth were immediately swept off into the basin of the sea, the earth would pass suddenly from inundation to drought, and would frequently remain for whole months deprived of that element without which it cannot exist a single day. The Great Disposer has, however, provided for this necessity; and the springs, the brooks, and rivers, images of His providence, will always flow. Two means have been employed to retain the waters on the summit of the globe, and thence to distribute them with a wise parsimony, that the supplies may be sufficient for the longest period of scarcity. The waters of the rains and condensed vapours collect in the mountain-cavities, to escape through the fissures of the rocks, and flow along the valleys; or else they hasten to accumulate in frozen masses on the loftiest points of man's dwelling-place, and melting slowly during the dry season, nourish the failing springs and lessening rivers. Some physicists have asserted that rain and the liquefaction of the snows count for almost nothing in the maintenance of the springs, which they represent as entirely due to the condensation of vapours. But these naturalists have never seen Nature *at home;* had they spent a few years among the mountains, they would speedily have acknowledged the magni-

tude of their error. It is *there* that the phenomena connected with the natural outflow of the waters must be studied. Not a mountain but has at its base or upon its flanks a multitude of fountains, the origin of which it is generally very easy to trace. Some begin to flow a few hours after rain has fallen, and run dry more or less rapidly according to their abundance; others flow only while rain is falling, because they are without a reservoir for storing up the waters; and others again are exhausted after a month, two months, or three months of drought, according to the capacity of the basin which supplies them; but all begin to run only *after* the rains, and their cessation occurs at the precise time when the condensation of vapours should be most abundant. At the foot of mountains crowned with everlasting snow are many springs which flow but in summer, because, unquestionably, they owe their origin to the melting of the glaciers. And, to conclude, you have only to see the fountains, torrents, and rivers, during the season of heat and drought, to be convinced that the glaciers are neither more nor less than vast water-stores, provided by the Divine foresight to meet the wants of organized beings.*

ADVANCE AND RECESSION OF GLACIERS — ABLATION.

The day will certainly arrive, nor do we think it is far distant, when we shall be able to refer the modifications which a glacier undergoes to those of the atmosphere, and *vice versâ;* but to establish with the precision required by science the chain uniting the two orders of phenomena, numerous meteorological observations are still necessary.

* Rendu.

So far as the action of the temperature is concerned, a very interesting fact requires notice; namely, the oscillating movement produced by the thaw at the extremity of a glacier, combined with the general progression of its mass. This thaw is sometimes so considerable as to prevail over the progression, and the glacier then recedes; if not, it continues its stately march, even during summer. The one or other effect takes place, according to the meteorological character of the year. In 1818, for example, when rain was frequent and the sky cloudy, careful measurements proved that the glacier of the Rhone advanced sixty yards; while in hot summers it recedes to a very perceptible extent.

When a glacier in any particular year makes a sudden advance, it causes a terrible desolation; overthrowing forests and villages, and frequently carrying its ravages into the cultivated champaigns. When, their progression being no longer in proportion to their fusion, they seem to retire, the lands invaded by them are given over to perpetual barrenness, for they are thick-strewn with pebbles, sand, and boulders.

In an exploration of the Chamounix Valley, made in the autumn of 1865, M. Charles Martins examined into the recessions, more or less considerable, of all the glaciers terminating in it, as well as into the diminution of their cubic solidity—that is, their aggregate thickness—by superficial evaporation and fusion; a phenomenon designated by the name of *ablation*.

Careful measurements show that the Glacier des Bossons has receded 332 mètres in twelve years; the Glacier des Bois, 118 mètres; that of Argentières, 181 mètres;

and that of the Tour, 520 mètres. The general cause of this recession would seem to be the small quantity of snow which had fallen in the two preceding years, and the heat of the summers.

After having ascertained the retreat and ablation of the glaciers at their lower extremities, M. Charles Martins felt desirous to learn the nature of the changes which had taken place in their upper portions; for this purpose he resolved to remount the Mer de Glace, and to ascend to the Col du Géant by the glacier of the same name.

The surface of the rock de l'Angle, polished and striated at an elevation of seventy feet, indicated that the Mer de Glace had lost a stratum of that thickness.

On leaving this rock, says Martins, I put my feet upon the ice, which I did not again take leave of; and upon the ice I advanced as far as the spot where the Glacier de Talèfre throws itself into the Mer de Glace, whose most important affluent it must be considered. The tourist who repairs to the *Garden*—an island rich in Alpine plants, situated in the middle of this glacier—formerly quitted the Mer de Glace at this point, to mount upon the *Couvercle*, the base of the Aiguille du Moine, and so to avoid the crevasses of the Glacier de Talèfre. This traject is now impossible; a ladder eighty feet high is needed, to reach the glacier on the Couvercle; a new proof of the ablation of the Mer de Glace at its confluence with the Glacier de Talèfre.

I crossed, continues our scientific traveller, the right lateral moraine of the Glacier du Géant, and raised myself on the western buttress of the Mountain de Tacul,

to take my night's rest on a great block known as the *Pierre de Tacul*, which serves as a shelter for the chamois-hunters and crystal-seekers.

It is a block of protogene, covered with black lichens, which has been arrested in its course about midway down the mountain, and projects sufficiently to enable three men to lie beneath it; a wall of bare stones completes this extraordinary mountain-asylum, which is situated about 320 feet above the glaciers, and 7800 feet above the sea. The surrounding soil is furrowed with marmot-holes, and the vegetation is of the character usually found at so great an elevation.

Few points are situated more favourably for a panoramic view of the Mer de Glace and its affluents. You can see the Mont Mallet, the Aiguille du Géant, the Aiguille and Glacier de la Noire, the Virgin, the Torch, the great Rognon, the Aiguille de Blaitière, the Monk, the Aiguille Vert, the Droites, and the Courtes, which dominate over the *Garden*. The Glacier du Géant is beneath the feet of the spectator; it has no medial moraine, and the parabolic strata of the ice are admirably defined between the lateral moraines. The latter are five in number at the Point du Tacul, on the right bank of the glacier. Four of these are lateral moraines formed by mountain landslips, on the right bank of the Glacier du Géant. The fifth is the left lateral moraine of the Glacier de Leschaux, which unites with the four others, and thus becomes one of the right lateral moraines of the principal glacier. In this place, new proofs of the recession of the glaciers were revealed to me. The Aiguille de Blaitière is opposite the Tacul. Small glaciers of the second order

descend from this aiguille, but do not reach the Glacier du Géant, above which they remain suspended. They are known as the "Glaciers d'envers de Blaitière." Between these glaciers and the surface of that of the Giant (*du Géant*), a strip of yellowish-green turf, about one hundred feet long, is visible. Above and below this strip, the acclivity is polished, striated, and deprived of all vegetation. The belt of turf, where the vegetable mould has remained, is a sign that at a certain epoch the Glacier du Géant was elevated above its lower margin, while the Glaciers d'envers de Blaitères descended to the upper; but its own area has never been invaded by the ice.

This belt shows us the extent of the *minimum* recession of the great glacier and its satellites at the epoch of their *maximum* power and extension. Now, on the contrary, the vertical distance between the surface of the Glacier du Géant and the lower extremity of the suspended glaciers is about 480 feet. The green strip is much nearer the surface of the Glacier du Géant than the escarpment of the Glaciers d'envers de Blaitères; for the latter, fed by small reservoirs, have receded much more in proportion than the Glacier du Géant has sunk down.

M. Martins reached the Col du Géant about midday, after a painful journey. He halted upon the rocks where, in 1788, De Saussure spent sixteen days at an elevation of 3362 mètres above the sea. Spite of the vapours which rose from the direction of Italy, he was able, when they occasionally cleared away, to enjoy the admirable spectacle presented by the southern slope of Mont Blanc. He saw the Glacier of La Brenva stretching beneath his feet; a glacier, the exact pendant of that of Bossons, and which

advances, like it, into the middle of the woods and cultivated fields. Its lower extremity had also receded by a distance estimated at about 975 feet. "I was fortunate," says M. Martins, in concluding his narrative, "in having visited the Col where De Saussure sojourned in 1788; and I congratulated myself on having succeeded, at the approach of old age, in an ascent which reminded me of those I had undertaken twenty years before without so much fatigue, but without any truer enjoyment of those sublime and eloquent scenes, which one would wish ever to have before him, if he has once comprehended their secret charm and unrivalled grandeur."

THE CREVASSES.

The name of *mers de glace*, which has been given to certain very vast and exceedingly irregular parts of the surface of the glaciers, originates in the fact that their appearance suggests the same term of comparison to every traveller who has sought to describe them. The surface of the glacier which is seen from Montanvert, says De Saussure, resembles that of a sea suddenly frozen,—and frozen, not in the hour of storm, but at the moment when the wind grows still, and the waves, though very lofty, are *émoussées* and rounded.

The numerous asperities of the *mers de glace*, and of some other parts of the glaciers, vary in form and elevation; their arrangement also presents a great diversity. Here are numerous little hills confusedly scattered about; there, ridges of ice are extended like long billowy swells, some of them extending from side to side of the glacier. Their summit, occasionally very acute, is not uniform, but

crowned with aiguilles, like the pinnacles of granite we so frequently encounter on the summit of the Alps. Between these hills and ridges stretch various little valleys of irregular depth, which have been created by the melting snows, just as rain-water furrows the lower grounds; they constitute a first kind of *crevasses*.

Their formation presents some remarkable peculiarities. The ice is not everywhere equally fusible; its most porous portions, and those which enclose deposits of earthy substances, melting most rapidly, the surface of the glacier is covered with small channels which quickly increase in depth, and if some of the closely-set crevasses are parallel, their intermediate sides form the long ridges of which we have already spoken. Continually washed by the snow-water, these sides are transparently coloured of a beautiful sea-green hue, or striped with blue and white bars.

On the crevassed surface of certain glaciers a curious arrangement is observable. If the traveller ascending the Glacier des Bois looks towards its source, he perceives numerous ranges of aiguilles and precipitous ramparts, frequently upwards of twenty feet in height; while, on facing towards the lower extremity of the glacier, the surface appears to be almost even. This arrangement of the ridges is simply a result of the orientation of the Glacier des Bois. As it is directed nearly from north to south, the solar rays strike the southern surface of the ridge, and the waters flowing from it continuously augment the fusion, while the northern face, protected from the sun, does not melt.

An accompanying illustration represents one of the

great glaciers of Iceland—that of the Svinafells-Jokull—remarkable for its crevasses and beautiful aiguilles. This enormous mass of ice is situated, as well as the lava-river contiguous to it, on the flanks of the volcano of Klofa-Jokull. It is split up in all directions, and at its most elevated point measures nearly two hundred feet in elevation. Its blue colour is frequently modified by blackish belts of volcanic dust alternating with the pure ice, and indicating, undoubtedly, the different epochs of the eruptions. The glaciers of this part of Iceland follow the volcanic chain, and extend uninterruptedly over an area of six to seven leagues, separated from the sea by a girdle of moraines. A veritable river, the Jokullsa, issues boiling from this immense sea of ice, through various springs, of which the least is as large as the great arch of the Glacier des Bois.

We have already spoken of another species of crevasses as produced by the mechanical tension which is exhibited in different parts of the glaciers, when any inequalities occur in their movement of translation. These are great fissures, generally perpendicular in the direction of the strata, varied in depth as well as in number, and abounding in localities where an angle or escarpment breaks up the channels. According to their position, they are divided into marginal, transversal, and longitudinal crevasses. The oblique tension resulting from the more rapid movement of the central parts produces the first named, which are directed from the edge of the glacier towards its source. The second make their appearance wherever the bottom of the valley changes its inclination; they divide the entire

GLACIER OF SVINAFELLS-JOKULL, ICELAND.

mass into a series of trenches, when these proceed to unite, as sometimes happens, with the marginal crevasses. Let us suppose the terminal portion of a glacier to be arrested or impeded by an obstacle; in such a case it is very strongly compressed by the force acting downwards, and if it can extend towards the sides, longitudinal crevasses will be seen to open.

The explorer also meets with points where the distribution of the crevasses is very irregular, and a great number interlace each other like the meshes of a net. The ice then divides into aiguilles, prisms, and pyramids, which, as they partially melt, assume the most fantastic forms. We reproduce the design of one of the fantastic figures which Professor Tyndall saw in 1859 on the dislocated surface of the Glacier des Bois.

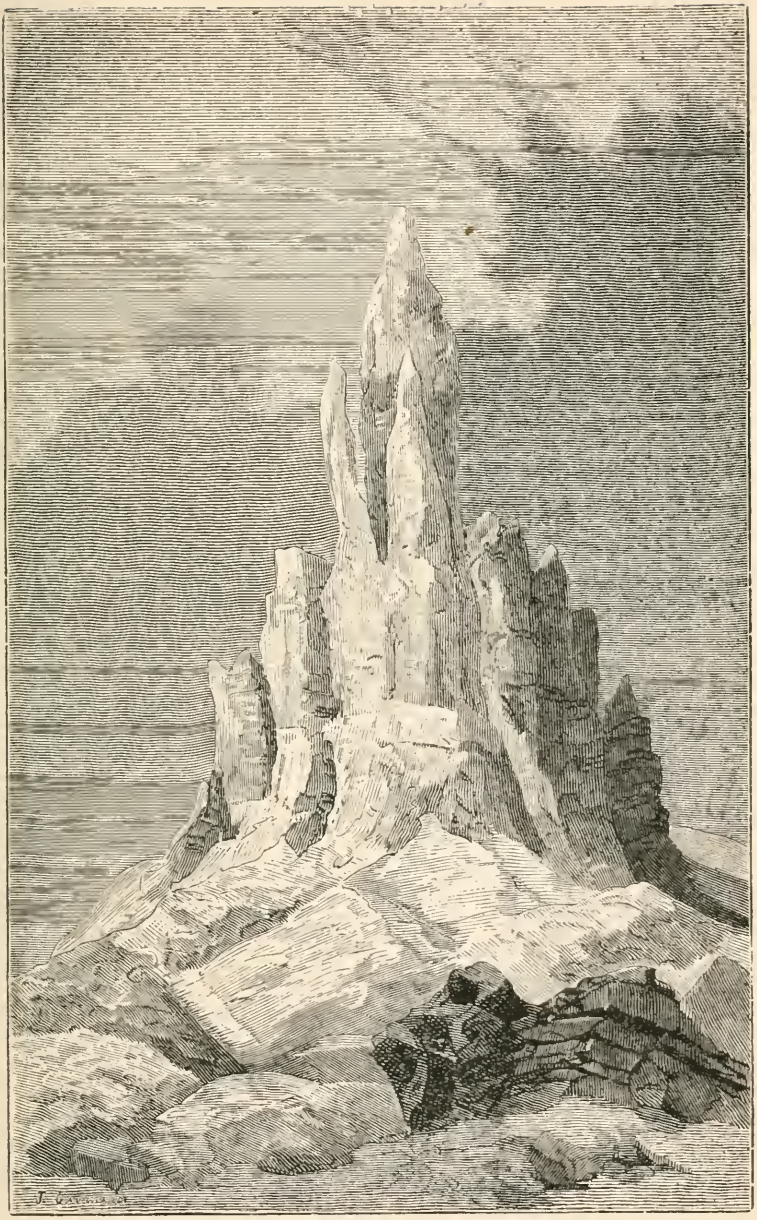
Hugi and Agassiz, the naturalists, during their prolonged sojourn upon the glaciers, had frequent opportunities of observing the formation of crevasses. They were always announced by violent cracks in the interior of the immense mass of ice, which each time experienced shocks like those of earthquakes.

Then there soon appeared on the surface a slight crack, the extension of which could easily be followed by the eye in the direction of its length. Afterwards it opened rapidly. A broad deep crevasse being thus suddenly formed, after a brief time it was seen to close again, and the work of regelation was so effectually performed that it was soon impossible, or nearly so, to distinguish the place where it had been from the rest of the glacier.

During his numerous explorations among the glaciers,

Professor Tyndall was present but once at the birth of a crevasse. He was traversing the Glacier du Géant, accompanied by a friend, when a hoarse noise, like that of a stiff gale, became audible beneath them. Loud detonations afterwards succeeded, but the intervals were filled with a continuous sound. They seemed to issue at widely separated points, sometimes higher up and sometimes lower down than the position of our travellers. It was evident that the glacier was breaking up, but the internal noises lasted for upwards of an hour without the slightest alteration being visible on the surface. At length a great quantity of air-bubbles traversed a neighbouring pool, and close by it a chink appeared, which could be followed for some distance in either direction, but was scarcely wide enough to admit of the insertion of a knife-blade. M. Agassiz has given a graphic description of the terrors which his guides experienced under similar circumstances; we ourselves, says Tyndall, were not free from a feeling of dread when the solemn silence of the evening was thus disturbed upon the glacier.

Numerous tourists have descended into the crevasses, and brought back curious particulars of these dangerous experiments. In the upper regions the walls of ice assume very irregular outlines, and are garnished with innumerable stalactites of all sizes, originating in the congelation of the threads of water which descend from the surface. Arcades, marvellously festooned, open into caverns, where the intruder finds himself suddenly enveloped in a glorious azure light. Sometimes, by leaning forward cautiously, you may obtain a hurried glimpse of



AIGUILLE OF ICE, GLACIER DES BOIS.

the dark chasm at the bottom, from which, as from a distant belfry, comes the ringing music of an impetuous torrent.

Berlepsch, in his valuable and exhaustive work upon the Alps, records some particulars of a descent undertaken by M. Coaz, a Swiss naturalist, to the bottom of a crevasse, near the lower extremity of the glacier of Morteratsch. The day was already far advanced, and under the influence of the heated air the fusion of the glacier proceeded rapidly. On penetrating into an excavation of some depth, M. Coaz saw the sides covered with a great number of round or elliptical air-bubbles. Many of these were traversed by the water trickling drop by drop, and appeared to beat with what may be called regular pulsations. At some points of the wall were little whirlpools of water, from a third to one-half an inch in breadth, moving with great rapidity. Not having noticed them on entering the grotto, the traveller thought they had been formed since his arrival, and probably through the increase of heat communicated by his body. These singular movements had taken place in cavities enlarged by the air-bubbles, into which the water penetrated after having traversed a very narrow channel. A ray of sunshine shooting athwart the orifice of the crevasse invested both the ice and the violently agitated waters with the most brilliant colours.

WELLS, OR MOULINS—GLACIER TABLES.

The snow-water which finds no declivity to provide for its escape remains *in statu quo*, hollows out a cavity, and sometimes bores right through the glacier and dis-

charges itself underneath, thus forming *wells*, or *moulins*.* These cavities are of different forms; frequently presenting on the surface of the glacier only a small circular hole, they afterwards grow much larger, and contract anew as they work towards the bottom; sometimes, on the contrary, the upper opening is of a tolerably large size, with winding borders. The canal exhibits these contractions and expansions, according as the strata of ice which it traverses are more or less compact or porous. During the entire course of the excavation it is filled with water to the very edge, a phenomenon easily explained by the change of density which this liquid experiences on changing temperature. The surface strata, warmed by the sun, by the air, and sometimes by the rains, may attain to 3°, 4°, or 5° above freezing-point; they then approach their maximum of density, and descend to the bottom, while the cold strata reascend, to come in contact, in their turn, with the atmospheric agents. The fusion operates through the heated water, until the latter cools back to freezing-point, and yields place to a new current coming from above. The whole seems a kind of mechanical agent employed by a high Intelligence to excavate this reservoir.

When the season permits of a prolonged thaw, or the well-hole is found in a shallow or porous part of the glacier, the canal strikes through to the bottom, and then becomes a passage for the superficial waters, which fall in a cascade towards the soil, and afterwards flow under vaults of ice to the lower extremity of the glacier. In

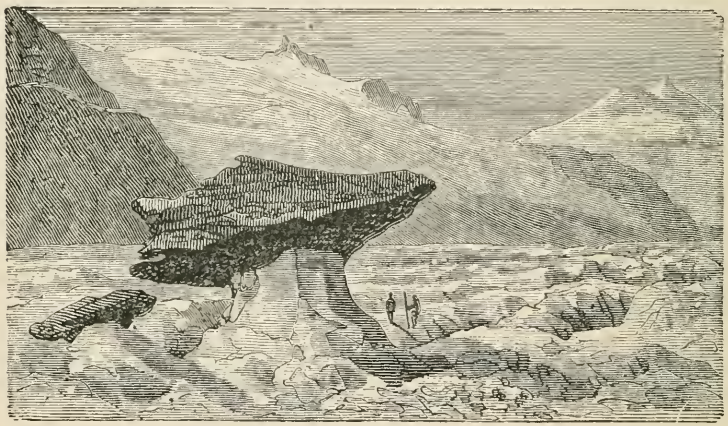
* So called, probably, from the resemblance of the hollow to the cavity in a mill-stone.

some of the moulins you can hear the waters dashing themselves, as it were, against the icy barriers which surround them. This may happen when the mass of the glacier is formed of various more or less compact strata superimposed on one another. If, then, a brook flowing at the bottom of a crevasse encounters some less tenacious parts, it necessarily melts them, and pierces a lateral canal which directs itself towards the moulins. Numerous cascades crossing one another at the bottom of such an abyss produce a din compared by travellers to the hoarse murmur of a hurricane or the roar of thunder.

The successive depression of the level of the glaciers, by the combined or alternate effect of fusion and evaporation, gives rise to certain remarkable phenomena, one of which has particularly impressed the popular imagination. Among the Alpine mountaineers a prejudice still exists which has been shared by numerous travellers and naturalists,—that the glaciers fling back upon their surface all the foreign bodies embedded in their interior. The guides, to indicate this fact, make use of an expression which concentrates on this subject the entire belief of the country: "The glaciers," say they, "preserve nothing impure." No mysterious force is necessary, in order that a rock, after having rolled into a deep crevasse, should gradually rise to the surface of the glacier. The superficial ablation caused by fusion and evaporation fully accounts for this phenomenon. Examine a rock still buried in the ice, and exposing to the air nothing but its point. This point, scarcely visible at first, will be enlarged at the end of a few days. In the course of a year its progress will be very sensible, and at length a moment

will arrive when all the rock shall be uncovered. Why conclude from this that the ice has rejected it? Is it not quite as easy to say that, the ice having diminished above and around it, it is found on the surface because this surface has sunk in proportion as the fusion has taken place?

The following fact, due to the same cause, appears at the first glance still more astonishing. When a great



GLACIER TABLE.

block of stone protects by its mass, against the action of the sun, the ice which it covers, the latter does not melt; and, while the general level of the glacier sinks, the stone is found eventually on the summit of a pedestal of ice, the height of which is in proportion to the activity of the fusion during the summer heats. To these stones the name has been given of *glacier tables*, which are met with on almost every glacier, but are specially abundant on that of the Lower Aar, near the Grimsel.

Professor Tyndall observed there some curious phenomena. The solar rays, falling upon the tables throughout the whole day, heat to the greatest degree their southern extremity, where a greater softening of the subjacent ice accordingly takes place, and the stones are progressively inclined towards the south. We may even say that their slope varies in accordance with the position of the sun; in the morning it is more towards the east, and in the evening towards the west. At noon these novel sun-dials indicate the direction of the meridian. The same circumstances, as the reader will easily understand, limit the duration of the suspension of the tables; acquiring daily a greater inclination southwards, they end by gliding along the glacier, which soon furnishes them with a new pedestal.

The great central moraines may be regarded as so many masses of glacier tables, for they all consist of long rocky ridges elevated several yards above the general level of the ice.

At various points of the glaciers we also meet with cones of very regular formation, composed apparently of an accumulation of gravel, and named "gravel-cones" by M. Agassiz. On examining them close at hand, you see that the surface stones are united together by the ice, which forms a kind of cement; and that the central part is constituted by a block of compact ice preserved from the action of the sun by this exterior stratum, while the glacier has melted around its base. These cones are wholly formed of whitish materials; when sand and minute fragments of rock are exposed to the sun upon a glacier, these bodies, instead of protecting the ice, warm it so far

as they come in contact with it, and sink insensibly into holes of tolerable depth thus excavated in the glacier.

You may note, on contemplating from a certain height the least agitated portions of the glaciers, a succession of black lines forming parabolic or ogival curves, with their convexity directed downwards. These are known as "dirt-bands," and, according to M. Charles Martins, are a consequence of the stratification of the glaciers. The latter results, as we have said, from different layers of snow in winter, which fall one upon another, leaving between them blackish deposits proceeding from atmospheric impurities. The fusion apparently gives to the edges of these strata a parabolic contour, elongated towards the bottom of the glacier.

GEOGRAPHICAL DISTRIBUTION OF GLACIERS—GLACIERS OF THE PLANET MARS.

The extension of the glaciers varies, as a rule, according to the latitude. Between the Tropics and in the Temperate Zones, they are found only in the upper valleys of the great chains. Nearer the Arctic Circle, they cover mountains of moderate elevation; and a stratum of ice has wholly invaded the lands nearest to the Poles.

The glaciers of the Pyrenees belong to the second rank, and are of small dimensions; the largest, those of Vignemale, Mont Perdu, and the Maladetta, suspended on the flanks of the mountains, do not descend into the valleys. In the Alps, on the contrary, glaciers of the first order predominate. An idea of their grandeur may be obtained from the following data:—The Mer de Glace of Mont Blanc alone, without counting the numerous second-

THE ALETSCH GLACIER.

ary glaciers, is 13,000 yards in length. The glacier of the Aar is 8744 yards long, with a width at some

GLACIER OF THE MALADETTA, PYRENEES.

points of 1500 yards, and a density on an average of about 260 yards; its volume has been estimated at 3280 cubic yards. The superficial area of the Aletsch exceeds 26,230 yards, and an approximative calculation gives twenty-two milliards of cubic yards as its volume. Six hundred glaciers are known to exist in the Alps; according to the naturalist Ebel, their total superficies cannot be less than 137 square leagues.

In the Caucasus, the principal summit of which towers higher than the peak of Mont Blanc, there are also some colossal glaciers; but, owing to the influence of the latitude, their extremities do not descend to so low a level as those of the Alps.

Resembling the Alpine glaciers, say the brothers Schlagintweit, in their mode of formation, and presenting the same physical phenomena, the glaciers are scattered in extraordinary numbers over Upper Asia, and yet it is only within the last few years that their existence has been sus-

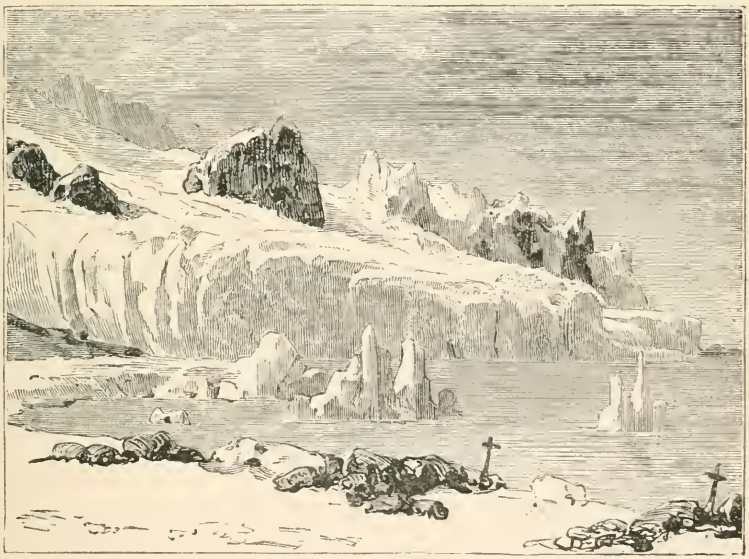
pected. Before the year 1842, it was not known that Upper Asia possessed *any* glaciers; nay, hypothesis had been piled upon hypothesis to demonstrate that the great chains in question could not have any.

Captain Montgomery, one of the officers charged with the trigonometrical mensuration of India, and a man of science distinguished by the conscientiousness and accuracy of his labours, says that the glacier of Baltoro, in the valley of Brahaldo, is thirty-six English miles in length, with a breadth varying from one to two miles and a half; each of the slopes of the Biafo gives rise to a glacier, and the two unite to form a river of ice, continuing over a course of fifty-four miles in an almost straight line, with no other interruption than that of the crevasses common to all phenomena of this class. Compared to these gigantic glaciers, those of the Alps may certainly be qualified as little.

The lower extremity of the glaciers of Upper Asia descend considerably below the perpetual snow-line, to a level of only 11,000, and even 10,000 feet above the sea-level, in the Himalaya chain. Some of the glaciers of Tibet descend still lower; that of Bepho sinks to 9876 feet. Those of Karakorum and Kouen-Loun offer the same characteristics as those of Tibet. It is a feature common to all, that they were formerly much more extensive than they are to-day.

The mountains of Scandinavia are comparatively of small elevation, but the formation of glaciers is favoured there by a cold damp climate. In approaching Iceland and the island of Jan Mayen, the voyager sees the

glaciers descending to the very shore; those of Spitzbergen pass beyond it, and periodically tumble headlong into the waters. Voyagers who ascend Baffin Bay and Smith's Sound have observed the same circumstance in connection with fifteen glaciers which, from the Greenland Alps, progress constantly towards the coast. Among them we include the gigantic Humboldt Glacier, which has been traced from the 79th or 80th degree of latitude over a course of



GLACIER OF BELL SOUND, SPITZBERGEN.

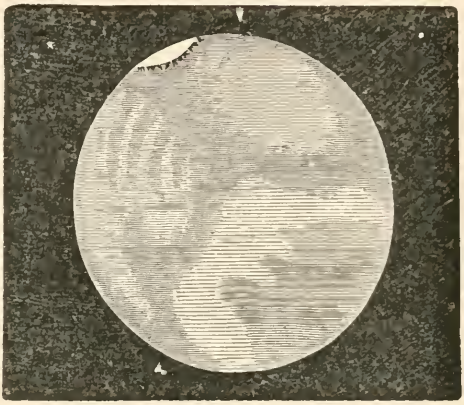
70 miles. The loftiest of the scarped terraces which terminate it is from 290 to 320 feet in height. No glacier is found on the north coast of Asia, except in Nova Zembla and Kamtschatka. That they are wanting in Siberia is due to that country's flatness and freedom from mountainous elevations. Hence the air is always extremely dry.

In the mountains of Tropical America, the small num-

ber of glaciers descending below the line of perpetual snow arrest their descent at a slight distance below that limit. They descend lower in the Temperate Zone, but it is when we reach the coast of Chili that we see them assume a great extension, and speedily reach the sea. In Eyre Bay, under a parallel of latitude corresponding to that of Paris, the illustrious author of the theory of Natural Selection, Mr. Charles Darwin, observed in one day more than fifty isles of ice detached from the shore, and steering towards the open sea. The Patagonian Alps and the mountains of Tierra del Fuego, continually receiving the humid winds of the west, are situated under the most favourable conditions for the formation of glaciers. The same is the case with New Zealand, where the Tasman glacier measures 10 miles in length by 2750 yards in breadth. In this island, as on the coasts of Chili, you have only to descend a few hundred yards below the extremity of the glaciers to find yourself in the heart of a tropical vegetation, among tall palms and arborescent ferns.

We shall describe in a future section the mighty glaciers which clothe the lands discovered by navigators under the highest latitudes, and the extent of which varies with the seasons in the course of every year. Modifications observed by astronomers in the aspect of the planet Mars, probably proceed in like manner from the formation and fusion of great masses of ice in the neighbourhood of its poles. If you examine this planet through a powerful glass, you will see that it is wholly besprinkled with greenish and reddish spots, except at two points, the extremities of its axis, where patches of a pure and brilliant white occur. The extent of these patches is

variable ; in proportion as that of one of the poles diminishes, the other progressively increases, in such wise that the minimum always corresponds with the summer, and the maximum with the winter of the hemisphere where the patch is situated,—as ought to be the case if to snow and ice we must attribute these appearances.



TELESCOPIC APPEARANCE OF MARS.

But, as Guillemin remarks, the white spots are not of the same extent either during their respective winters or summers. The snowy cap of the southern hemisphere varies within much greater limits than that of the opposite pole : it is much more extensive during the winter season, and it diminishes during the summer to such an extent that it does not occupy more than the fifth part of the superficies of the snowy spot of the northern pole. This difference is easily explained by the great inclination of the axis of the planet to the plane of its orbit, and by the fact that the southern pole is turned towards the Sun, when Mars is nearly at its smallest distance from the focus of light and heat. The summer time, on the other hand, of the northern hemisphere, occurs at the epoch of its greatest distance. The qualities of heat received by the globe of Mars, at these two opposite points of its orbit, vary in the ratio of seven to five.

III.

The Glacial Period.

GEOLOGICAL LANDMARKS.

DURING the summer of 1815, an erudite geologist,—M. de Charpentier,—who was exploring the glaciers of Switzerland, and had taken for his guide a chamois-hunter, began a conversation with him on the mode of transport of blocks of granite which are often found at a considerable distance from their point of origin.

In opposition to the then generally accepted hypothesis, that these blocks were carried from place to place by currents of mud and water, Jean Perraudin, who, in his wandering life, had attentively observed the various glacial phenomena, was of opinion that the causes anciently at work differed in no respect from the causes still in operation; and that the glaciers, which were formerly of much greater extent, had transported, as they still transport, the boulders detached from the summits overhanging them. This opinion, the result of intelligent observation of facts occurring under our own eyes, was soon adopted by the majority of geologists, and assisted them in the solution of a problem whose difficul-

ties have apparently increased in proportion as science, embracing a wider field of view, has grasped it in all its grandeur.

It was in the same year that Professor Playfair, after having explored the environs of Geneva and Neufchâtel, declared that the huge blocks of granite he had met with, and many of which had been used as Druidical stones, had been transported by an immense glacier, extending from Mont Blanc to the Jura. This explanation, based on the state of preservation of the blocks, the sharp edges of which were scarcely modified, did not, at first, attract the attention of the scientific world. But after his conversation with Perraudin, M. de Charpentier, by collecting facts and comparing observations, was soon brought to admit the probability of an ancient extension of the glaciers beyond their present limits. After a prolonged examination of the subject, which ended by establishing in his mind a complete conviction, he declared his opinion in the most positive form. Since that date, numerous researches, conducted in all parts of the globe, have demonstrated that wherever mountainous masses rise present traces are visible of the phenomenon observed in the Alps ; and the hypothesis of an ancient extension of the glaciers has been elevated to the rank of a scientific theory by the majority of naturalists whose daring explorations have thrown so vivid a light on the last geological epoch of the world's early history. Some have even hazarded the idea that there were two glacial periods, separated by a period corresponding to the present in its general features, but during which certain animals existed which have long ago disappeared. We shall here

speak only of the last of these periods, immediately posterior to the appearance of Man upon the earth.

DESTRUCTION OF THE HIGH SUMMITS.

Ramond has graphically described the phenomena which induced the destruction of the high peaks, and play an important part in the history of the glaciers :—

"Why can we not," he says, "construct a sufficiently abrupt incline to prevent the accumulation of snows upon it, under a rock capable of resisting the avalanche-shock; a solid, warm, and well-stored habitation, where an observer might be present at those revolutions from which Nature has hitherto debarred all living creatures; might be a spectator of those phenomena which, for so many ages, have had no witnesses; might submit to his scientific calculations and measurements the conflicts of elements, the rapidity of the winds, the might of displaced snows, the convulsions of air and earth? How many events would succeed each other, hitherto unobserved and unknown; how many sensations, how many new ideas! What a spectacle when once the storms of autumn should have seized upon these regions as their own domain; when the agile chamois and the sombre crow, sole inhabitants of the deserts, should have fled the heights; when a subtle snow, carried down from slope to slope, and flying from rock to rock, should have engulfed under its capricious waves their barren extent; when the summits, surrounded by an impenetrable cloud, should long have been hidden from the gaze! Then what terrible tempests! What whirlwinds! What hoarse shudderings in the bosom of the mountains! How deep a

silence when victorious winter should no longer find any enemies to overcome; when the sun, waxing pale in the sombre depth of the heavens, should reappear only to throw an oblique glance on the icy summits; when, in the prolonged obscurity of the nights, the moon should seem to draw nearer and nearer, in order to pour, with its beams, the deadly chill of the ethereal regions!.....

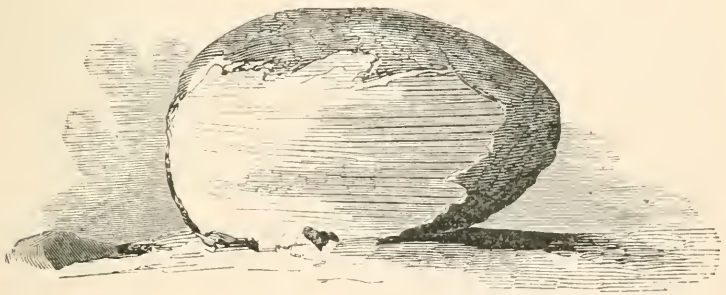
"But the sun resumes its power. At the coming of May, which already prevails over the plains, it comes hither to pursue the winter into its last intrenchments. Capricious at first, and its brow shrouded with light mists, it dissolves them into soft rains, which open the earth to the influence of the spring.....Soon it attacks the frost with all the might of its rays; the air kindles, earth grows reanimated; every instant sees the immense mass of December snows crumbling into nothingness..... A triumph imperfect, and yet more terrible, than that of winter itself!.....Not a moment of silence or repose; the avalanches roll and bound in every direction with the impetuosity of the torrent and the roar of the thunder; the waters, long enchained, now escape from their forced tranquillity, and sweep in every direction; the rocks, split by the ice, crumble and rend, and with their ruins desolate the verdant slopes.....

"Such is now the condition of the heights which dominate over the globe. Time, which lightly skims the surface of the rest of the earth, prints them with ineffaceable vestiges of its passage; and while, elsewhere, it disguises for us the rapidity of its course, by carrying onward ourselves more quickly than the majority of the objects which surround us, in the mountains it displays

all that is terrific in velocity. It shelters under our eyes an edifice which to our feebleness seemed impregnable, and it changes in our presence the forms which we were accustomed to regard as eternal. In the plains, Time seems to pause when it gives existence, when it develops, and when it sustains it; we learn that it has passed only when we see it destroying its own work. It is not spring, crowned with flowers; it is not autumn, prodigal of its fruits; it is not the brilliant succession of sunny days, which remind us that the seasons fly. The melancholy sentiment of their instability penetrates us for the first time when the leaf falls, when the tree withers, when the days grow brief, when Nature, lamenting, closes the circle of her reproductions. Among these rocks, on the contrary, among these mountains which the frosts of an eternal winter encircle, nothing distracts us from the contemplation of Time's ravages. Every moment marks its passage upon them; every minute deals them a perceptible blow. The snow desolates them continuously; the torrent rends them incessantly, and their ruins crumble unintermittently!"

The blocks and fragments which, through the crevasses of the glaciers, or through the space intervening between their lateral walls and the flanks of the valley, have formed the deep moraine, are, for the most part, reduced into mud by the enormous pressure they are forced to undergo. If they resist, the colliding fashions them into a rounded form, and covers them with a network of striations. It is important to remark here that water, while it polishes and rounds the pebbles, does not striate them,—and even, in the long run, effaces the striations

traced by the pressure of the glaciers. One understands that the blocks which remain suspended between the rock and the sides of the glaciers present the same appearances as those belonging to the deep moraine, while the blocks of the lateral and medial moraines, brought to the surface, and having to undergo the action only of atmospheric agents, preserve nearly always their forms and their primitive dimensions,—dimensions which sometimes extend to as much as sixty-five feet in every direction. These gigantic blocks, transported to great dis-



STRIATED BOULDER.

tances by the ancient glaciers, have received the name of *erratic blocks.*

ERRATIC BLOCKS.

The presence of erratic blocks in the plains of Northern Europe, and on divers other points of the terrestrial surface, constitute one of the most important phenomena of geology. For the most part, these blocks have been detached from the neighbouring mountains. In some countries they are comparatively rare, and scattered, as it were, haphazard; but generally we find them accumulated in groups like dykes, the curved outline of which varies,

and which take different directions. Deposited among the rocky débris and masses of sand or gravel, the erratic blocks seem sometimes worn by friction, and then exhibit exactly similar striations to those upon blocks belonging to the moraines of the glaciers.

Stones which are not of a very hard substance are rarely found in erratic soil, which is composed of sand, loam, clay, and fragments of granite, limestone, porphyry, and the like. The great boulders, sometimes isolated, do not always proceed from mountains near at hand; frequently considerable distances, and the sea itself, separate them from the chains to which they originally belonged. Thus, the blocks scattered over Denmark and Northern Germany have been transported from Norway and Sweden; and in Poland and Prussia we meet with fragments from the mountains of Finland. In Russia, Holland, Germany, and Brittany, are also found fragments of granite and porphyry, which are all of northern origin. On the coasts of England, and in the plains of Yorkshire, geologists have recognized certain boulders as belonging to the coast of Labrador. The declivities of the Jura, the plains of Piedmont and Lombardy, are covered with innumerable blocks, in which may be detected the species of granite which constitute the bulk of Mont Blanc and of the surrounding summits.

ERRATIC BLOCK, WALES.

The great dykes formed by these blocks circumscribe the extremity of most of the lakes of Upper Italy, which owe their existence to them, and have therefore been designated *morainic lakes.*

M. Charles Martins, speaking of the quarrying of the granitic blocks which largely compose the ancient moraines on the declivity of the Alps, demands very justly that some of these blocks should be *classed* as historic monuments, so as to transmit to posterity a striking evidence of the ancient extension of the glaciers. In our opinion, such a demand deserves to be seriously considered; and we even think that other remarkable indications of the changes and revolutions of which our globe has been the theatre, might be very usefully preserved in the localities where their presence attests at once the prodigious labour of nature and the grand discoveries of science. Such monuments would direct the thoughts of the passer-by to the magnificent mystery of creation every day more and more unveiled by human genius, which teaches us to know the beneficent designs of the Creative Intelligence.

Traces of the erratic phenomenon,—plainly visible, as Mr. Geikie has shown us, on the Scottish mountain-ranges, as on those of Corsica and the Lebanon,—are particularly striking in the valleys of the Vosges and the Jura, where the ancient glaciers are of the same magnitude as the existing glaciers of Switzerland. The mountains of the Auvergne and the Cevennes do not appear to have ever contained any glaciers, perhaps on account of the

slight elevation of the greater portion of these two chains, and of their southern situation. M. Charles Martins also invites us to observe that the granite which they yield,—granite which elsewhere furnishes the most durable erratic blocks,—is very easily decomposed. Moreover, the violent eruptions of the numerous volcanoes of the Auvergne may have destroyed all traces of the ancient existence of glaciers.

On the northern face of the Pyrenees traces of glaciers and erratic blocks are everywhere abundant. The southern slope also presents characteristic signs of the same phenomenon, which appears to have extended no further in Spain than the mountains of Galicia. In Africa, the chain of the Atlas exhibits no single vestige of the erratic soil.

A not less important phenomenon than that of the erratic blocks has been observed in the mountains contiguous to them. The surface of these mountains, upon the escarpments, upon the angles, and in the bottom of the valleys, is not only worn and polished, but shows also numerous furrows and striations, in general parallel, which can only proceed from the passage of the glaciers. The transport of these enormous blocks was for a long time attributed to enormous diluvian currents, which carried down with them mud, and sand, and gravel. But, in this hypothesis, all the blocks ought to present the traces of such a violent mode of transport, while, most frequently, their remarkable state of preservation proves that they have undergone no other degradations than those arising from atmospheric agencies; and, consequently, they can have been transported only by glaciers or floating ice.

ANCIENT GLACIERS.

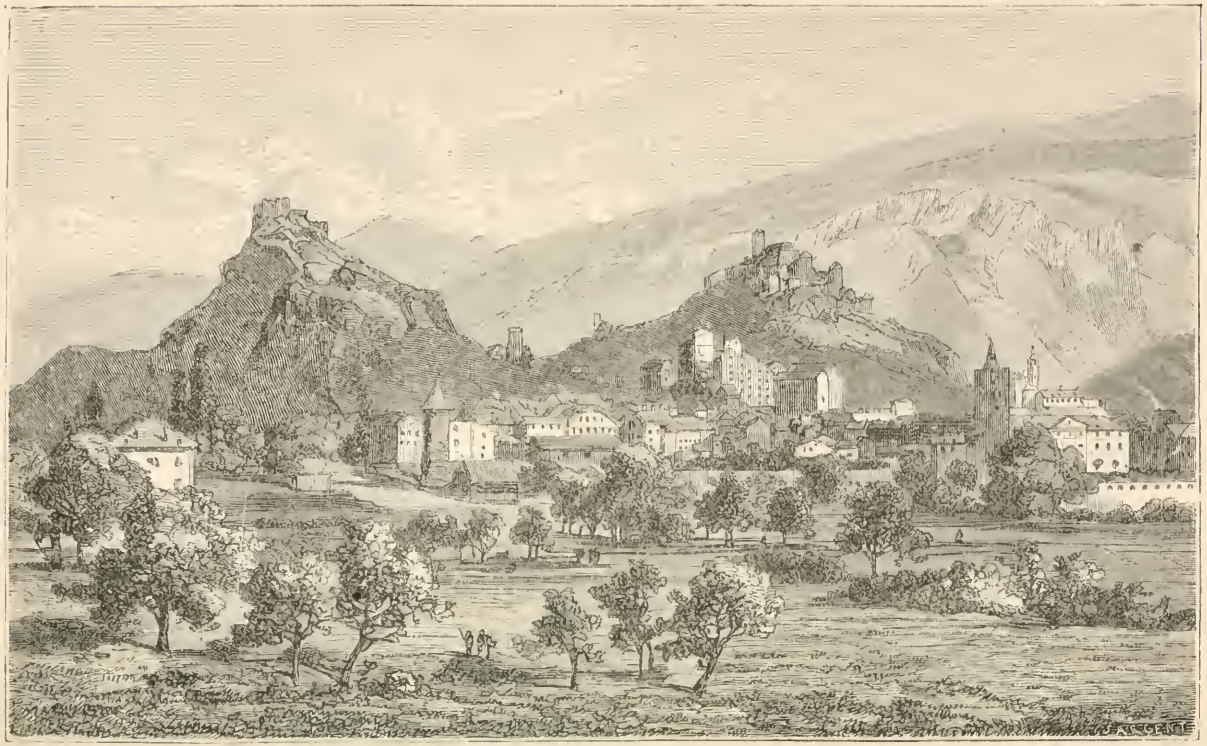
The elaborate monograph in which Charles Martins demonstrates the ancient extension of the glaciers of Switzerland, brings together abundant evidence of the numerous signs still extant of a period when the greater portion of the terrestrial surface was buried under ice. We regret that we cannot follow the learned physicist, some of whose interesting observations we have already reproduced, in his curious examination of the ancient glacier of the Arve, pointing out with him the traces of every kind which testify to its prodigious development during the Glacial Period. Analogous traces render not less evident the existence of other mighty glaciers which formerly debouched in that of the Arve. Instead of being built up with granitic blocks, the moraine of these affluents is frequently calcareous, like the mountain which dominates over them; and the supposition of a diluvian current cannot explain this difference of mineralogical composition between the rows of blocks deposited on the banks of one identical torrent, which would, in truth, have heaped them up pell-mell.

After having cleared the Salève Mountains, and doubled its extremities, the glacier of the Arve flung its last boulders on the Mont de Sion, situated near Geneva, where the waters divide which flow on the one hand into Lake Leman, on the other into Lake d'Annecy.

Upon the two slopes of the Mont de Sion, says Charles Martins, the geologist meets with erratic blocks of a very varied nature, and recalling to his memory the mountains where these rocks are accumulated in considerable

masses, he acquires the conviction that he has discovered the meeting-point of these great antediluvian glaciers: that of the Rhone, which filled the entire basin of the Leman; that of the Isère, which, debouching by the Lakes of Annecy and Bourget, extended as far as Lyons; and that of the Arve, which, intercolating itself between them like a sharp wedge, terminated near the village of Vers. The humble Mont de Sion was, as M. Arnold Guyot says,—and it is to him we owe this splendid discovery,—the point whither all those mighty glaciers converged which have so profoundly modified the surface of the plain comprised between the Alps and the Jura. We shall not follow them all in their traject, for all would present the same features as those of the glacier of the Arve. Let us content ourselves with tracing the general limits of the ancient extension of these glaciers.

"The glacier of the Rhone had its sources in all the lateral valleys which cut through the two parallel chains of the Valais, and wherein are found the most elevated mountains of Switzerland, Monte Rosa, Mont Cervin, the Jungfrau, and the Velan. It filled the whole district of the Valais, and stretched down into the plain comprised between the Alps and the Jura, from the Fort de l'Ecluse, near the famous *Perte du Rhone*, right into the environs of Aarau. This was the principal glacier of Switzerland, and carried down those innumerable blocks which cover the Jura up to the height of 3500 feet above the sea-level. The other glaciers were simply feeble affluents of the glaciers of the Rhone, incapable of making it deviate from its direction. Thus, where the glacier of the Arve encounters it on the ridge of the Salèves or on



MONT DE SION, NEAR GENEVA.

the declivities of the Voirons, you can discover, by the arrangement of the moraines, that the glacier of the Rhone continues its progress, while that of the Arve abruptly pauses. In the same manner a rapid river drives back the feeble rivulet which brings it the tribute of its waves.

"The other secondary glaciers occupied the principal valleys of Switzerland. Such were the glacier of the Aar, which, with its terminal moraines, crowns the hills in the neighbourhood of Bonne; that of the Reuss, which has covered the borders of the Lake of the Four Cantons with blocks dragged from the summits of Saint Gothard. That of the Linth halted at the extremity of the Lake of Zurich, and the town of Zurich is built on its terminal moraine. Finally, that of the Rhine, which has not been so fully investigated as the others, occupied the whole basin of the Lake of Constance, and descended as far as the boundaries of Germany."*

FORMATION OF THE ALPINE "RELIEF."

We have already pointed out that, on the southern slope of the Alpine chain, the ancient glaciers descended also into the plains of Upper Italy, and had left *there*, as on the northern slopes, the most indubitable traces of their passage. The same imprints produced on the rocks by the movement of the glaciers, occurring in most of the mountainous countries of the globe, it becomes evident that the valleys of those countries have been excavated by an agent whose incomparable power was in proportion to the prodigious travail of Nature at the

* Charles Martins, "Du Spitzberg au Sahara" (Paris, 1866).

epochs when the latter constructed our terrestrial abode. It is enough to compare the dimensions of the present glaciers—generally reduced to some 19 or 20 miles in length, and 125 to 250 yards in thickness—with the dimensions of the ancient glaciers, which were frequently 150 miles in length, by 1000 to 1250 yards in depth, to obtain an idea of the erosive force proportionate to such a development.

In Professor Tyndall's "Notes from the Alps," which appeared in the *Saturday Review*, occurs an interesting passage.

He had asserted, during the summer of 1863, that the Alps in their present formation were due to the action of ice-water. The majority of persons who had visited these mountains received the assertion with a smile of incredulity. Well, he continues, from the spot where he was then posted, down to the bottom of the valley, was a difference of, at least, three thousand feet. The valley itself is covered with trees and verdure. Villages built wholly of wood are scattered over its surface, and the cows upon the grassy hillocks tinkled their merry bells. Yet there is not a square foot of this fertile land but was formerly buried in ice. Look at yonder rocks: their ridges are not sharp and covered with asperities like those of the higher summits, but, on the contrary, extraordinarily smooth. All the asperities have been worn down. How? By an immense glacier, which formerly filled the valley, took possession of the basin now occupied by the Lake of Geneva, rolled into the plains of Switzerland its congealed waves, and halted only before the remote barrier of the mountains of the Jura. At

BED OF AN ANCIENT GLACIER.

the bottom of this same valley the glacier marched; slowly, it is true, but with resistless energy. This is the modelling tool which has rounded the rocks; the ploughshare which has worked such deep furrows in the mountain-side, and whose passage has left in its rear those long banks of moraines. This powerful tool could not act during the incalculable period of time occupied by the Age of Ice, without profoundly modifying the structure of the prominence against which it was exercised. If such a prominence had been, at the outset, perfectly uniform, and composed of materials of equal tenacity, there is no doubt that the water, by its solvent effect, and ice by its mechanical action, would have polished regularly the surface. But in nature there is nothing uniform.

ARCTIC GLACIERS.

The generality of this great phenomenon is especially visible when we consider how immense a surface is invaded by the glaciers of the Northern Pole, which stretched into Eastern Russia, into Scandinavia, into the British Isles and North America, touching upon Finland, England, and the latitude of New York.

This invasion has left traces of every kind which our naturalists have discovered, not only on the chains anciently covered by the Polar glaciers, but also on the upheaved strata, where, on the frozen surface, lie the erratic blocks transported thither by icebergs and ice-fields across the seas of which these strata formed the bed. The numerous boulders scattered over the sandy plains of Northern Germany and European Russia had long been specialized as natural curiosities. Men were ignorant

whence these blocks proceeded, they could not understand how they had been transported; they had greatly impressed the popular imagination, and in the mysterious ceremonies of the Druidic worship they played an important part. The southernmost boulder in Germany, in 51° 16′ N. lat., marks the place where Gustavus Adolphus fell on the victorious battle-field of Lützen.

A French geologist, Durocher, some thirty years ago, attributed the erratic phenomenon of the northern countries of Europe and America to an immense deluge, caused by an enormous mass of water directed from the Polar Regions towards the south. But Elie de Beaumont rightly observed that the perfect preservation of the erratic blocks was an incontestable proof of the presence of enormous icebergs in the torrent which traversed our hemisphere. In fact, scientific observers were puzzled, at first, to understand how it was possible for these blocks, after traversing hundreds of leagues, to have preserved the sharpness of their outlines. Their enormous weight precluded the supposition that they could have remained suspended in the fluid mass, and consequently they must have been moulded and rounded by their collision against the surface of the rocks.

If geologists are not in agreement as to the cause of this last cataclysm, all have, at least, been struck by the immense quantity of débris which are scattered over our continents, and which bear witness to the grandeur of the phenomenon formerly ascribed to revolutions that had elevated the great mountain-chains, to dislocations of soil entailed by these movements of elevation,—dislo-

cations which, by breaking through barriers and lowering shores, might have produced, after the appearance of the principal Alps or of the chain of the Andes, the prodigious irruption of waters to which may be referred the accumulation of alluvial matter, blocks, rolled pebbles, sand, and gravel, known under the name of the *Northern diluvium*. It would seem, moreover, infinitely probable that these movements, due to the action of an unique and instantaneous cause, have also caused the partial deluges recorded in the traditions of every nation, and which still threaten considerable regions, such as the great valley of Lower Canada, or the fertile slopes of the Caspian Sea, situated beneath immense reservoirs of water.

Convinced of the marvellous power of a slow, continuous action, such as is still taking place under our eyes, and being partisans of the glacier-theory, we are nevertheless of opinion that we ought not to seek in a single principle the unique cause of all geological phenomena, and we adopt the view (which seems to us very judicious) put forward by Adhémar:*—"One error which leads many excellent thinkers astray is, their absolute desire to refer a great number of different facts to a single cause. According to them, a theory is absurd if it does not explain everything. They long for an hypothesis that shall furnish a complete solution of all phenomena. A natural law which will perfectly account for erratic blocks or diluvium is rejected if it does not also account for the rupture of the strata or the formation of the mountains, and *vice versâ*. But there is no reason why all obscure

* Adhémar, "Révolutions de la Mer," 2nd ed. (Paris, 1860).

facts should have the same origin, and I think we shall arrive more surely at the truth by seeking a particular explanation for each phenomenon."

To De Saussure, Leopold von Buch, and Humboldt, we owe the theory of elevation so scientifically developed by M. Elie de Beaumont, whose persevering labours have enabled us to ascertain the comparative age of mountains by studying the upheaved strata and the strata in their original position,—one of the most remarkable discoveries in geology.

In our work on "Volcanoes" we have indicated the manner in which this illustrious physicist has developed the theory of the parallelism of contemporary mountain-chains; a theory which opportunely completes the discovery of a pentagonal network traced by the aggregate of chains of different dates in the world's history. The pentagon is the figure after which the fixed surface of a molten globe, diminishing in size as it decreases in heat, must necessarily split up, so that the travail of the forces causing the disruption shall be as limited as possible. The secular cooling of our planet will, then, have been the cause of the deformations of the terrestrial crust and of its unity of structure. Views such as these, even if more numerous observations in the still unexplored portions of the globe should lead to their modification, do not the less contribute important facts to the treasury of science, stimulating to fresh researches and leading to further progress. They teach us, moreover, to consider, with Herschel, all geological revolutions rather as the necessary and regular effects of general causes than as the result of convulsions and catastrophes which no law

regulates, and which cannot be referred to any fixed immutable principle.

CLIMATE OF THE GLACIAL PERIOD.

The most recent discoveries relative to the Glacial Period prove, at the same time, that this period must have been of enormous duration, and that it passed through several alternations of temperature. Numerous observations have enabled us to recognize in the ancient glaciers numerous successive phases of extension and recession, corresponding probably to as many phases of partial elevations and subsidences. These oscillations were the cause, not only of changes in the elevation of the mountainous masses where the glaciers have their cradle, but also of considerable variations in the geographical distribution of the seas, and in the direction of the great oceanic currents,—variations which are evidently related to those of temperature.

Thus, for example, the great desert of Sahara has been formed by the recent upheaval of the bed of a sea extending from the Gulf of Gabès to the north of Senegambia. At this epoch the *sirocco*, to which in Switzerland is given the name of the *föhn*, and which diffuses over Europe a part of the burning heat of the Desert sands, swept over the vast extent of that ancient sea, though its temperature was considerably lower. It could not then melt, as it does to-day, almost while you gaze, the snow on the mountain-summits, and limit the encroachments of the glaciers.

The most considerable of the great oceanic currents, the Gulf-Stream, which rises in the Gulf of Mexico, and with its warm waters moderates the winter cold in the

countries of Western Europe, detaching from the shore the mighty glaciers originating in the valleys of Spitzbergen, has not always, it is probable, followed the same direction, depending also evidently on accidents which may have modified along its passage the relief of the terrestrial crust. It is easy to comprehend the part which such a change must play in the distribution of heat over the surface of the globe, if we remember the following description :—*

On issuing from the Gulf of Mexico, the Gulf-Stream is not less than 3000 feet deep, and 60 miles wide; its swiftness, in the Strait of Florida, equals four miles an hour. It afterwards follows the coast of America, in a northward direction, and spreads its waters over the sea like a mantle of heat, covering an immense extent, and sheltering myriads of creatures, which, during winter, and even on the shores of Europe, find in it an abundant supply of food. If the heat transported by this prodigious current could be utilized, it would suffice to maintain in constant activity a Cyclopean furnace, able to pour forth a current of molten iron equal in volume to that of our greatest rivers. To this beneficent heat it is that Ireland owes the verdure which has procured her the name of the "emerald-isle of ocean," and our western shores the fertile pastures which even in mid-winter, when all things are covered with ice in the corresponding latitudes of America, provide the shepherd with nourishment for his flocks.

Mr. Hopkins, the eminent geologist, has clearly proved

* Maury, "Physical Geography for the Young."

that phenomena analogous to those of the Age of Ice would be reproduced in Western Europe, if the Gulf-Stream were diverted from its actual course. During this period, the continent of North America, the emersion of which is relatively recent, would cease to exist, and the Gulf-Stream would flow over the site of the present valley of the Mississippi.

On the other hand, Constant Prévost remarks that an earthquake which should shatter in twain the isthmus of Panama, and which, as a consequence, should change, or at least modify, the direction of this mighty current, would lead to great changes in the European climate. According to the same authority, it was sufficient if a great part of Europe were covered with water at the close of the Tertiary Epoch (which observation has proved), for that region to be placed under conditions of humidity and temperature favourable to the establishment and extension of the glaciers.* Prévost adds, that if the rupture of the isthmus coincided now-a-days with a similar submergence, the glaciers of our mountains would speedily descend into the plains.

Analogous considerations, tending to connect the explanation of the glacier-phenomena with the doctrine of present causes, have been put forward by Sir Charles Lyell, in his "Principles of Geology." These considerations explain the alternations of mild and severe climates, and the preservation of species in the more temperate zones during the Age of Ice. Charles Martins has, moreover, shown very clearly that the immense development

* "Comptes-Rendus de l'Académie des Sciences," tome 32.

of the ancient glaciers by no means necessitated such an extreme of cold as one might at first be led to imagine. It is in effect evident, from what we have already said in respect to the transformation of snow into ice by repeated fusions and congelations, that this phenomenon could not occur with a climate of extreme severity. On the other hand, a very simple calculation as to the perpetual snow-line of Mont Blanc proves that this limit will descend as far as 800 yards for a decrease of 4° only in the mean temperature of Geneva. If we allow that the glaciers of Chamounix were equal then in magnitude to their present dimensions, and no more, we shall see that their base would be on a level with the Swiss plains. And as these glaciers, having for their basin of supply enormous *cirques*, or amphitheatres, must also, for this reason alone, descend much lower, we can understand their ancient extension to the environs of Geneva; an extension which, however, has been the work of many ages.

Thus, then, the great phenomena of the Glacial Epoch may be accounted for by a simple diminution of 4° in the mean annual temperature of the countries where we discover their traces.

Some of the manifold causes which may have produced these climatic variations we have already indicated; it remains for us to offer a summary of Professor Tyndall's beautiful and interesting studies,* which tend to show that the primary cause of the Glacial Period was—not cold, but heat!

We have said that the glaciers are fed by the snow

* Professor Tyndall, "Heat Considered as a Form of Motion."

accumulated in the *cirques* or amphitheatres of the upper regions. This snow, descended from the atmosphere, proceeds from the condensation of the aqueous vapour produced under the influence of the solar rays, and the abundance of this vapour is as essential as cold to the rapid formation of the glaciers. To produce itself, says Tyndall, snow has need of its primary material, which material, the aqueous vapour of the air, is the direct product of heat.

It is perfectly plain that by weakening the action of the sun, either by a diminution of its emitting power, or by making the whole solar system traverse a space of low temperature, we should destroy the glaciers at their source. Vast masses of mountains of ice infallibly necessitate adequate masses of atmospheric vapour, and, on the part of the sun, an energetic action in the same proportion. If in a distilling apparatus you wish to augment the quantity of liquid distilled, you surely do not attempt to obtain this augmentation by removing the fire from beneath your cylinder; yet, if I rightly understand the matter, this it is which those physicists have done who have attempted to account for the formation of the ancient glaciers by the diminution of the solar heat. It is altogether evident that the most indispensable thing for the production of glaciers is a *perfect condenser;* we cannot afford to lose an iota of the solar action; if we have need of anything, it is of more vapour, and especially of a condenser of such power that the vapour, instead of falling in liquid showers upon the earth, shall be so lowered in its temperature as to descend in the shape of snow.

Professor Tyndall adds to these considerations an important observation on the causes which, together with the depression of the summits, have contributed to the retreat or disappearance of the ancient glaciers. The rapidity of descent of these enormous masses being in proportion to their dimensions, and their passage giving rise to vertical pressures equal to 500 tons per square yard, the reader will comprehend how irresistible must have been their action on the soil and even on the hardest rocks. In opening thus a way towards the plain, in hollowing the profound valleys where the temperature no longer permits the water to preserve its solid form, and which send, like immense draught-chimneys, great currents of hot air towards the heights, the giants of the Glacial Period were preparing their own disappearance. The glacier moves, and works. Like living bodies, it moves because it moves itself. And when it disappears, it has assisted, according to its strength, in opening up new channels for the migration of species, and in preparing the ground for the development of moral life with all its complications and its beauties. So that no truly religious heart can be otherwise than filled with emotions of love for the great energies of Nature, in the midst of the calm of the summer nights of Switzerland, while in the vanished glacier it evokes one of those powerful workmen whose strong and patient hand has chiselled the figure of the earth.*

* On the interesting subjects discussed in the foregoing section, the reader may consult Professor Tyndall's "Glaciers of the Alps," and "Heat Considered as a Form of Motion;" and an able paper by M. Félix Foucon, in the *Revue de Paris*, for September 1864, entitled "Sur le Mouvement des Glaciers et le Climat de la Période Glaciaire." See also Sir Charles Lyell's "Principles of Geology."

IV.

The Alpine Glaciers.

"All that expands the spirit, yet appals,
Gathers around."

GLACIERS OF THE ALPS.

AFTER having thus concisely stated the principal laws which govern the formation and movement of the glaciers, we now proceed to a description of these remarkable phenomena. The limited space to which we are confined, and their absolute identity of character and aspect in all parts of the globe, render it advisable for us to confine ourselves to the Alps, and to select our descriptions from the narratives of travellers and men of science who have explored that mighty chain, and contemplated the impressive grandeur of the magnificent landscapes which it offers to the admiration of men.

The first thing which strikes us as we approach the glacier-region is the dazzling aspect of its enormous masses, of its huge mountains of silver sown with greenish spots to indicate the deep and narrow fissures which divide the

glacier. When examined from a nearer point of view, these crevasses, which in the interior exhibit a wall of transparent ice, change in colour according to the play of light, and assume successively a purple tint, celestial blue, or the most exquisite violet. Beyond the ice, the vast billows of which surmounted by crests brilliant as crystal rise to the very mountain-peaks, and seem suspended above the valleys, the eye discovers the range of black rocks and sharp pinnacles whence crumble headlong the shattered rock boulders which accumulate on the edges and in the centre of the glaciers. It is impossible in words to give any description of the beauty of these vast amphitheatres when their transparent surface glitters in the sun, and its blinding whiteness is here and there relieved by the great shadows of azure blue descending from the mountain-summits. Frequently, the declivities which hem in the lower portion of the glaciers are covered with glorious woods of a sombre green, and these form a striking contrast to the whitely-gleaming ice, at whose foot rich pastures lie extended, and vineyards, and cultivated fields.

In their present condition, the Alps present two principal and contiguous *mers de glace*, or seas of ice; one to the north-east, the other to the south-west.

The former encloses the mountains which stretch in one huge chain from the St. Gothard and the Grimsel to the Schreckhorn; the latter, the formidable peaks comprised between the St. Bernard and Mont Blanc.

From these two seas issue a multitude of branches, crossing and blending with one another, descending the

MONT BLANC.

slopes like congealed torrents, piling up the abysses, invading the valleys, and pouring their frozen waves into the plains, even into the very centre of the harvest-field.

According to places and circumstances, the glaciers exhibit a great variety of forms and aspects. Towards the mountain-tops, in regions where they can freely extend, their appearance is that of a calm sea, rippled by the wind. In contracted passes, and narrow defiles, the sea is converted into a raging torrent, whose floods press and dash upon one another in apparently boundless fury. Sometimes, fragments of ice detached from precipitous rocks remain erect like transparent pinnacles or spires. Great masses are bent into the shape of semicircular arches on the brink of the precipices; and when this projection yields, a dazzling wall of living ice is seen aloft at a terrific elevation. In these strange and eëry regions everything recalls the idea of movement, and yet Silence reigns there, interrupted only by the fall of rocks, the crash of avalanches, and the roar of the storm.

During the winter-time a white shroud is thrown over the frozen waste, and blots out every vestige of life. The snows invade the immense chain of the Alps, interrupt the communications, accumulate in gorges sheltered from the tempest, in the hollows of the valleys, in the amphitheatres, and there make ready for the glaciers new stores of sustenance.

In the first days of spring, a warm breath frees the lower declivities from the thick mantle under which

the fresh verdure of the Alpine valleys has been preserved. The pastures reappear, the firs shake their rime-loaded boughs, and the sun restores to activity the waters flowing from the melted snows, which are confined within the limits traced for them by the hand of Summer. These waters, absorbed by the great crevasses which in every direction intersect the ice, flow in the lower canals which they help to hollow out, nourish the failing springs, and pour themselves into the beautiful plains they fertilize through caverns opening at the foot of the glaciers under the influences of the heat.

TRAVELLING ON THE GLACIERS.

If the luminous beauty and picturesque aspect of the glaciers attract numerous travellers, who, for the sake of contemplating them, brave the fatigues of a frequently perilous journey, it is to men of science that we are more particularly indebted for the most complete and most interesting descriptions, not only of the phenomena which these extraordinary regions offer to our investigation and curiosity, but also of the varied spectacles they present in each successive season, and at every hour of the day or night.

The pacific conquests of science, demanding always that persevering will without which no discovery is possible, demand also the firm resolution, the patient energy which place at the service of our kind the noblest of human virtues, the virtue of self-sacrifice. One of the most daring Alpine climbers of France, M. Dollfus-Ausset, has collected in a most interesting volume the principal narratives of the intrepid explorers and the devoted *savants*

to whom we owe our knowledge of the glaciers.* From these narratives we borrow the following descriptions, selected so as to furnish our readers at one and the same time with a complete idea of the fantastic character of their frozen solitudes, and of the perils incurred by those who courageously traverse them for the sake of studying their wonders.

THE CREVASSES—SNOW-BRIDGES—THE NEVES.

We shall prefix to each narrative the date of the exploration and the name of the explorer.

ASCENT OF MONT BLANC.

By Henri B. de Saussure—August 1787.

We entered upon the Glacier de la Côte, opposite the blocks of granite in whose shelter we had slept. The access to it is very easy, but soon afterwards you become involved in a labyrinth of rocks of ice separated by broad crevasses,—here, entirely open; there, filled wholly or partially by the snows, which are frequently built up into the shape of arches, and are often the only means of traject across these crevasses; elsewhere, you must make use of a ridge of ice. In certain places, where the crevasses are absolutely empty, you are compelled to descend to the very bottom, and afterwards to mount the opposite wall by steps cut in the solid ice with your hatchet. But nowhere do you touch or even see the rock; the bottom is always snow or ice, and there are moments when, after having descended into these abysses, and surrounded by

* "Matériaux pour l'étude des Glaciers." By Dollfus-Ausset (Strasbourg, 1864). Vol. iv., "Ascents of Mountains."

almost perpendicular walls of ice, you cannot imagine to yourself where or how you will effect your escape. Yet, so long as they march upon the living ice, however narrow may be the ridges, however rapid the declivities, these intrepid guides, whose head and feet are

DE SAUSSURE'S PARTY IN THEIR ASCENT OF MONT BLANC.

equally firm, do not appear either terrified or disquieted; they converse, they laugh, they chat with one another: but when you are passing over those thin vaults suspended above the abysses, you see them move along in the deepest silence; the three first, bound together by

ropes at a distance of three to six feet between them, the others, in couples, leaning on their iron-shod poles, their eyes fixed on their feet, each endeavouring to plant his foot lightly but firmly in the footprint of his predecessor.

But it was more particularly at the place where, on a former occasion, one of our guides had sunk and perished, that they redoubled their precautions. The snow had failed suddenly beneath his feet, leaving around him a void of six to seven feet in diameter, and had revealed an abyss, neither whose bottom nor whose sides were visible; and this at a spot where no external sign indicated the least appearance of danger. So, when we had crossed one of these suspicious snowy patches, and our caravan found itself once more on a rock of solid ice, every face was brightened by an expression of joy and serenity; the babble and the jests recommenced: there we held counsel on the route it were best to follow, and, reassured by our success, exposed ourselves with greater confidence to new dangers.

We occupied, in this way, about three hours in traversing the formidable glacier, though it was scarcely a quarter of a league in breadth. Thereafter we walked only upon the snows, often rendered very difficult by the rapidity of their slopes, and sometimes dangerous when those slopes terminated upon precipices, but where, at all events, you fear no other danger than that which you see, and run no risk of being engulfed without strength or skill being able to render you the slightest assistance.....

After an hour's progress, we found ourselves skirting an immense crevasse. Though it was upwards of one

hundred feet in width, we could not see the bottom anywhere.

While we were all standing on its brink, admiring its depth, and observing its successive strata of snow, my servant, through some distraction of mind, let fall the stand of my barometer; with the swiftness of an arrow it glided down the sloping side of the crevasse, and planted itself at a great depth in the opposite wall, where it remained, fixed and quivering, like the spear of Achilles on the bank of the Scamander. My regret was keen, because this stand served for my compass as well as for my barometer, for a telescope, and for various other instruments to which I was accustomed to fit it. Some of my guides, perceiving the trouble I was in, offered to undertake its recovery; and as I would not consent from a fear of exposing them to danger, they protested that they incurred no risk.

Immediately one of them slipped a cord under his arms, and the others let him down until he reached the barometer stand, which he seized and brought back in triumph.

During this operation I was a prey to a twofold anxiety: first, and chiefly, for the safety of the adventurous guide; and, secondly, as we were opposite to and in sight of Chamounix, whose inhabitants, with a glass, could follow all our movements, I thought that if at this moment any eyes were fixed upon us, they would think without doubt that one of our party had fallen into the crevasse, and we were endeavouring to recover him. I afterwards learned that, at this crisis, happily no one was observing us.

We were compelled to cross this same crevasse on a rapid and perilous bridge of snow; after which, by a still swifter snowy incline, we approached one of the last rocks of the isolated chain, where I slept the day afterwards on returning from the summit, and which I therefore named the *Rock of the Happy Return.**

ASCENT OF MONTE ROSA.

By Messrs. Zumstein,† Vincent, and Molinatti—July 1820.

Zumstein represented the *névé* of Monte Rosa as one of the most extraordinary and majestic scenes in the entire

MONTE ROSA, SHOWING THE LYSKAMM.

region of the Alps. It forms an oval cirque, the total length of which is estimated at a five hours' journey from east to west, and a two hours' journey from north to south. In this immense space only snow and ice, only ice and snow, are to be seen; at the very border, the rock alone is an exception. Around it are reared in a semicircle, like so many colossi, the five loftiest summits of the

* "Voyages dans les Alpes," by H. B. de Saussure.

† M. Delapierre, inspector of forests, a distinguished glacier explorer, better known under his German name of Zumstein.

group and the Lyskamm, a large crevasse from which the great glacier of Monte Rosa escapes; towards the west, the eye is arrested by the magnificent pyramid of the Matterhorn. No sounds, no life exist in this icy solitude; not a sign of the vegetable refuse which the wind frequently scatters upon the glaciers; not even the phenomenon of red snow. From time to time a crow whirls round affrighted, to descend precipitately to less ungenial regions.

There was something ominous in the appearance of this desert; the more so that a cloudy veil gathered over the sky, and the mists began to hang heavily on the summits. Our guides retraced their steps to meet M. Molinatti, and Zumstein remained alone. For two hours he searched among the chaotic confusion both right and left for a suitable spot where he might pitch his tent, and pass the night. He could not discover one; there was not the slightest rocky projection to serve as a shelter from any sudden storm; the whole surface was hillocky and bare. At length, by dint of a careful survey in every direction, he detected towards the extremity of the cirque, at a point where it began to incline in a northerly direction, an undulation or depression of the ground. Thither he repaired in all haste. Unhoped-for good luck! It proved, 'tis true, a very singular, and, indeed, a very terrific asylum; but, at all events, it was better than nothing, and the position was one in which fastidiousness was ridiculous. The said shelter was neither more nor less than an immense crevasse, a score of feet in depth, whose bottom appeared to be paved with solid snow, accumulated there by the winds. It stretched from

GLACIERS OF MONTE ROSA.

south to north; and as it measured fifteen feet in width, there was sufficient space for those who wished to make use of it. Contented and delighted with his discovery, Zumstein retraced his steps to show his companions the way.

It was six o'clock in the evening; night approached, and the porters, loaded with provisions, fuel, and a tent, had not made their appearance. The thermometers, which during the day had kept at 8° above freezing-point, had sunk to 7° below. This enormous difference—fifteen degrees in a few hours—told all the more keenly upon Zumstein, robust as he was under other conditions, because, having suffered severely from heat in a previous expedition, he had been imprudent enough to clothe himself very thinly.

He was on the point of swooning, and, losing courage, was about to fall into a polar sleep, when the leader of the party, the old and tried hunter, Joseph Beck, perceived his condition, seized him, and began to rub him, or rather to scrape him, so vigorously that he put him on his feet again.

The cold continued to grow more intense, and with it their sufferings also increased. Picture to yourself these men, at an elevation of 13,000 feet, in 7° of frost, and with the prospect of still severer cold before them, without succour, without fire, without food, in the open air, on the hard ice, exposed to all the violence of the hurricanes which frequently burst forth at such a height. Those persons, says Zumstein, who are acquainted with the upper regions of the ice, may form an idea of the dangers which threatened us. Their position became in-

supportable; all had resolved to turn back, and dare the horrors of a descent in the darkness, when, to their immense relief, the porters at length appeared, and restored them to hope.

They approached the crevasse on the northern side, where an incline of 25° conducted them to its edge. There the venerable Beck, arming himself with an axe, excavated in the ice a flight of forty steps, and then descended to the bottom of the gulf, which he sounded in every direction to assure himself of its solidity. The rest of the party then followed in his steps, and all were soon reunited in the very heart of the glacier. What lay beneath them? None could say. Would the snow bear their weight all night? They did not know. Might a storm rise with the dawn of day? It was to be apprehended; and if so, all must have perished, buried under the snow or in the depths of the abyss. But, for the moment, their sole thought was to make themselves as comfortable as they might: those least overcome erected the tent; in a short time some hot soup was served up, and victoriously combated the effects of the frost. This new kind of bivouac was certainly the most exalted which had been attempted in Europe, and must have formed a singular tableau, calculated to inspire an artist's pencil.

Submitting themselves to the hand of Providence, our adventurers, eleven in number, wrapped themselves up in their cloaks and coverings, lay down upon the slope as close to one another as they could press, and slept soundly until the morning, without any suffering from the cold, except the first and last of the file. In the middle of the night Zumstein was awakened by palpita-

tion of the heart, which almost choked him; he got up and walked about to recover himself, and was speedily better. About three o'clock, one of the guides, having risen to light the fire and prepare the breakfast, was attacked, on opening the tent, by so terrible a gust of wind, and such a cloud of snow-drift, that he returned in hot haste, and threw himself down again among his comrades.

Towards six o'clock, the wind having subsided, and the cold being somewhat mitigated, each was soon on his feet, and hailed with intense delight the first rays of the sun which penetrated into their asylum. They revealed to the gaze an extraordinary and unexpected scene. The south-eastern extremity of the crevasse was formed of a vault of the purest and most beautiful azure ice, where a thousand crystals sparkled like diamonds in the light of day. To the roof of the cavern hung innumerable blocks of ice, shaped like cubes, cylinders, and pyramids, which threatened every moment to fall headlong, and the débris of which were strewn over what we must call the soil or floor of the grotto. The light reflected from the azure walls gave each face a ghastly livid hue, which added greatly to the strangeness of the spectacle. The eastern side descended perpendicularly to an unfathomable depth, and was striped all over with belts of different shades, varying from three to four inches in width, and lying in a north to south direction. These belts, which indicated the successive formation of the strata of snow, could be counted up to one hundred before disappearing in the obscurity of the abyss. An icy shudder quivering through their limbs prevented the spectators from

remaining in the cavern so long as they would have wished. They penetrated into it, however, as far as prudence permitted, and to a distance of some two hundred paces from the mouth. From the elevation of the roof above their heads, Zumstein estimated at a hundred feet the thickness of the upper stratum of the ice, at the lowest point which they reached.*

PASSAGE OF THE SCHWARZ-THOR.

By Mr. John Ball†—August 1845.

The following narrative we adapt from an account furnished by the distinguished president of the Alpine Club,—one of the most useful institutions, from every point of view, which have been founded to encourage both the zeal of the naturalist and the enterprise of the traveller. We regret that our limited space precludes us from giving Mr. Ball's graphic description *in extenso*:—

What joy, asks Mr. Ball, can be compared to that of a morning excursion among the great Alpine glaciers, in the profound silence of Nature, in the midst of the sublimest spectacles? A vivifying air communicates vigour and elasticity to every muscle, the eye is refreshed, and the whole being trembles with pleasure at the thought of the adventures the rising day will bring with it. It was in this frame of mind that I advanced, a little in front of my guide Matthias, in the vast shadow which the mountain-peaks spread over the vast surface of the Glacier of Gorner, when an incident occurred of which I fear I can give the reader but an imperfect idea, spite of

* "Bibliothèque Universelle de Genève," tome xii. (1861).
† "Peaks, Passes, and Glaciers."

my vivid recollection of the charming impression it produced upon me. We were approaching the moraine of the glacier; the air was calm, silence everywhere prevailed; the myriad of tiny runlets which, the evening before, furrowed the ice under the influence of the heat, were now silent, and fantastic channels marked the trace of their passage along the porous surface of the glacier.

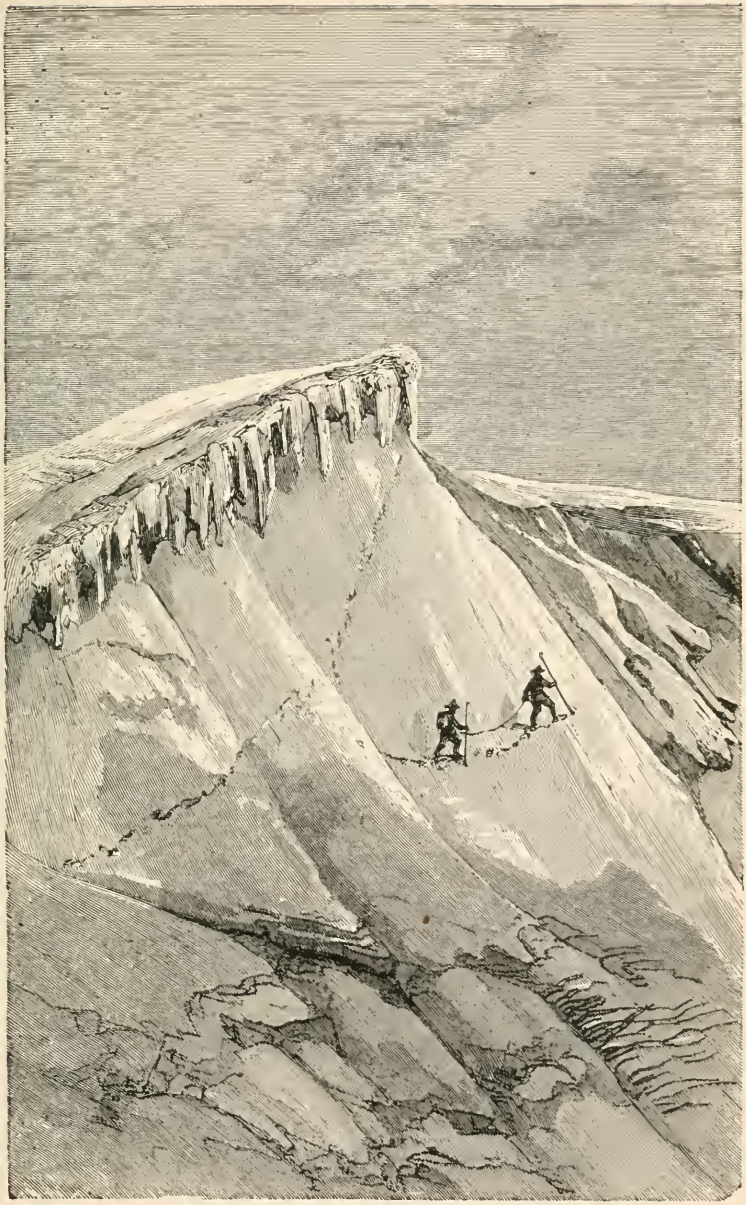
Suddenly I thought I heard, as if it came from a prodigious distance, the soft and feeble sound of musical instruments. I paused, and listening attentively, could no longer doubt that my impression was correct. I asked Matthias what was his opinion, but he could give no idea of the probable cause of these sounds. I then remembered that travellers, passing the night at the Grands-Mulets, had heard the sound of the bells of Cormayeur; and I imagined that some fête was being celebrated in one of the Italian valleys of Monte Rosa, the direction whence the sounds appeared to proceed. We continued our advance, the sound continuing, and growing rapidly stronger as we approached a narrow and deep crevasse, where the mystery was explained.

Far below us, in the interior of the glacier, a brook fell in a cascade from one ledge of ice to another, and the crevasse beneath our feet transmitted to us, like an organ-pipe, the sonorous vibrations produced by the current in the elastic mass of ice. Two interesting conclusions resulted from this curious observation into the laboratory of the glacier. It was proved to us, in the first place, that the movement of water in the interior was not arrested by the night, and, consequently, that a strong frost probably does not extend far below the surface; in the

second place, that fissures parallel to the surface of the glacier do not exist only at its lower extremity, where they are always found in the roof of the caverns whence the waters flow, but that probably they are produced in all directions over the entire extent of the glacier.

I had often suspected that the water filtered through the ice during the hot season found here and there a channel of escape, nearly horizontal, in the interior of the glacier; but, during the day, the noise of running waters rises on every side, and it would be impossible for the ear to follow the trace of an isolated stream. Now, on the other hand, in the heart of the silence, I could distinctly assure myself that the stream rippling beneath us descended by a slightly inclined plane to the edge of the crevasse, whence it fell into the interior of the glacier.

We advanced rapidly, and had soon traversed the great glacier, keeping a little to the right of the Schwärzeberg. The lower part of the Glacier de Schwärze was easily crossed, but afterwards we came upon the fresh snow, which had fallen in great quantities a few days previously. I then got ready the rope for immediate service, winding it firmly around the body of each of us. Our difficulties began at the intersecting point of the two systems of great crevasses. The first snow-bridge gave way beneath my feet, and I sank up to my waist; but, with the help of my pole extended over the surface, I had no difficulty in climbing back again. It was the first time such an accident had occurred to me, and as I was anxious to keep Matthias in a good humour, I treated it very lightly. But the worthy man was not the less deeply troubled, and besought me to abandon an enter-



ASCENT OF THE GLACIER DE SCHWARZE.

prise full of danger. I explained to him in a few words that the rope was sufficient for our security, and he consented to follow me over a new and more solid bridge, which we soon began to traverse.

We had then in front of us, and on our left, the great cliffs of ice which I had seen rearing their heads in the distance, and which presented not a single sign of issue. On our right opened the labyrinth of broad crevasses, through which I determined to seek a passage, following up the base-line of the precipices. But this wall of ice, which rose to the south, had sheltered from the sun the thick mantle of snow with which the icy ridges between the crevasses were covered, and it was neither easy nor safe to launch one's-self from one ridge to another upon this indurated snow.

However, in spite of the time it would occupy, I resolved to essay them systematically, one after the other, so that no chance of success might be lost. Some of the snow-bridges supported us; others crumbled away like the first; eventually, I thought I had found a passage, but a few blows with my pole on the bridge spanning a large crevasse dashed it in fragments into the azure depths of the yawning abyss, and I was forced to leap backward.

After new and vain attempts at other points, Matthias, judging this part of the glacier to be impracticable, cried, with an accent of triumph,—"I told you we should be compelled to return." But he was singularly disconcerted when he saw that for a final effort I was about to attempt the escalade of the ice wall which confronted us with its almost vertical face,—offering at some points, however, a

slope the inclination of which I estimated at nearly 60°. The snow, which everywhere else I found an obstacle, here proved of great utility. It furnished us with a firm *point d'appui* to attempt to raise ourselves on the ice which it covered, and which, but for this circumstance, I should not have dreamed of attacking. I therefore put myself *en route*, taking the lead, and tracing the way with an excessive precaution.

The scene was extraordinary; I had never seen the ice broken up in such imposing masses. Sometimes, after having laboriously reached, almost on one's hands and knees, the summit of a declivity upwards of one hundred feet in height, we had to descend into a deep hollow, where we could see nothing but the sky and the threatening aiguilles of ice arising in all directions. More than once I was compelled to pass exactly beneath the ledges of snow fringed with long icicles which surmounted every slope. We then advanced softly and silently between these icicles and the wall of ice, carefully avoiding touching them, lest the slightest shock should induce the fall of the frail vault suspended above our heads.....

At length we reached the outer edge of an immense mass, suspended at a great elevation above the glacier. I had climbed to the summit, in the hope I might descend on the opposite side, but there I encountered an almost vertical wall of ice, sixty to eighty feet high, and I was compelled to right about face. On examining the slope, I came to the conclusion that if we could traverse it lower down, we might be able to continue our route. The inclination was at least 60°, and when Matthias saw me preparing to attempt this perilous passage, he recom-

menced his protestations, louder than ever, with the countenance of a man who is marching to certain destruction.

I was compelled, therefore, to assume the tone of command, telling him that if he followed exactly my instructions he had nothing to fear, but that the slightest disobedience would assuredly prove fatal to him.

And as, in reality, I wished to risk nothing foolishly, I took unusual precautions. Anxious to give my companion the utmost possible security, I advanced slowly, leaving in the snow plain marks for each foot, as far as the rope permitted; and, arriving at the end, I planted myself solidly on the slope, with the help of my long pole.

Then I gradually hauled in my rope, at the same time that Matthias advanced towards me, holding myself ready to pull upon it if he should unfortunately slip. I was specially afraid of his turning dizzy if he threw his glance towards the yawning crevasses of the glacier which extended far beneath us, and I ordered him to keep his eyes continually fixed on the traces where he was to set his feet.

After repeating this manœuvre three or four times, we arrived, near the summit, on a less abrupt declivity, some twenty or thirty feet only from the table-land so long desired.

PASSAGE OF THE STRAHLECK.

By Messrs. Agassiz, Desor, Pourtalès, and Coulon—August 1840.

After having sojourned for a week under a rock on the medial moraine of the glacier of the Aar,—the Hôtel des Neuchâtelois,—we resolved upon realizing our favourite project, that of attempting the passage of the Strahleck,

by crossing the sea of ice which separates the glacier of Finsteraar from that of Grindelwald.....

From our hut to the foot of the Strahleck, which forms the point of partition between the two glaciers, is a journey of three hours at the ordinary rate of progression. The inclination of the glacier throughout the whole extent is not very considerable, which enables one, therefore, to travel very quickly and very conveniently. For the most part the crevasses were covered with a roof of snow hardened by the frost, and consequently presented no danger. They were visible at some distance off by their tint, which is duller than that of the glacier; so that those who feared to place their feet upon them could easily leap across, or double round them at their leisure.

As we drew nearer to the ridge, the crevasses became wider and yet wider; some we saw were fully ten and fifteen feet broad; but as these, like the former, were covered with snow, and this snow had become as hard as the walls of ice, we crossed them with perfect confidence. Not a few might be regarded as secondary crevasses; that is, the mass of hardened snow which filled them had been split asunder since its accumulation,—a manifest proof that this *remplissage*, though less compact than the mass of the glacier, must still be endowed with a considerable rigidity to have been able to crack in this manner. At the very foot of the Strahleck the glacier presented a quite peculiar appearance.

The reader will easily understand that in the midst of these solitudes, which cannot but be uniform, and, therefore, monotonous, in spite of their imposing grandeur, the least objects became of interest to us. We thought

nothing of long digressions, nor of crossing the most painful crevasses, to pick a little stunted plant, or examine a stone or lichen of singular appearance. It is the privilege of science to furnish the naturalist at every step with new subjects of recreation and meditation.....

Having reached the bottom of the incline, we might either have directed our steps towards the Zœsenberg, on the left, or have immediately begun the ascent of the Mettenberg; but our guides, to save time, advised us to skirt the right bank of the glacier, which seemed to them the most direct route.

It was here we met with the greatest difficulties of our expedition. The crevasses suddenly became so numerous, that we were compelled to pass along the border by scaling the vertical walls of the ice-cliff; but hardly had we made our way for a few moments upon the rock before enormous precipices yawned in front of us; we had, therefore, to regain the glacier, and seek a painful path among the upheaved and fissured masses of ice. Once we were on the point of retracing our steps; but the idea that a few more yards would bring us to the Grindelwald route gave us courage; and after much exploring, Jacob at length discovered a way of descending from the rock to the glacier. Not one of us stumbled among all these difficult windings and passes, which afforded us several opportunities of admiring the extraordinary skill of our guides, and the remarkable suppleness of their limbs.

A little further, we came in sight of one of the finest spectacles to be enjoyed among the glaciers.

An enormous mass of ice was loosened from a lateral

branch of the glacier of the Eiger, and with an awful crash precipitated itself on the glacier of Grindelwald. As it fell from a tremendous height, its fall lasted several minutes, during which we could see the icy ball make the most extraordinary leaps, and finally alight on the surface of the glacier, covering it with a great white patch which from a distance seemed like fresh snow. It sometimes happens that through an accident of this kind the moraines are temporarily buried under the ice; but this ice quickly melts, and the débris of the rocks again appear on the surface.

We were now close upon a small periodical lake, the termination of the comparatively level portion of the glacier, which is called, by unanimous consent, the Mer de Glace of Grindelwald. Lower down, the glacier is not practicable. The shepherds have carried thither a number of large planks, which they throw across the great crevasses to serve for a bridge; but the crevasses, like all the other superficial accidents of the glaciers, being subject to continual variations during the summer, the old ones closing up, and new ones opening parallel with them, it frequently happens that the planks are swallowed up in the glaciers, or else they lie alongside the crevasses. This is the critical moment for tourists; and it is only the most adventurous who will cross these bridges without parapets.

A spontaneous exclamation of joy broke from all our troop, when, on doubling a rocky projection, we suddenly descried before us the church and village of Grindelwald. The valley had never appeared to us more beautiful. We felt our eyeballs, previously contracted by the glittering

GLACIER OF THE GRINDELWALD.

reflection of the ice and snow surrounding us on every side, dilate with pleasure as they rested on the green turf watered by the crystal Lutschine. Assuredly, I advise all persons who think themselves weary of the familiar beauties of our Alpine valleys to pass some time among the glaciers, and I promise them that, on their return, they will find their faculties of appreciation quickened.

In the lower part, the glacier of the Grindelwald is more convulsed and irregular than any other glacier of the Oberland; and, in this respect, it contrasts singularly with the glacier of the Aar. The aiguilles are there developed on an immense scale, and in its labyrinth of fissures and crevasses the direction of the moraines can be but imperfectly distinguished. The flanks of the Mettenberg are rounded, and furrowed by tortuous channels up to a great height, and everywhere we recognize the traces of a very great extension of the ice. This fact is strongly illustrated by the huge erratic blocks of gneiss which we meet at every step upon our path, and which can have descended only from the upper regions of the glacier, since the Mettenberg is entirely calcareous.*

ASCENT OF THE SCHRECKHORN.

By Messrs. E. Desor, Escher de la Linth, and Girard—August 1842.

Many of our Alpine travellers, when they find themselves face to face with the great peaks, are astonished at their comparative want of elevation.

They expect to see summits of a more precipitous character, and have much difficulty in reconciling themselves

* "Nouvelles Excursions dans les Glaciers et les Hautes Régions des Alpes," by E. Desor (Paris, 1845).

to the idea that such and such a pyramid, or such and such a cupola, which is said to be 10,000 to 12,000 feet in height, is really ten times loftier than certain cliffs which they have climbed on the sea-coast, or twenty to twenty-five times higher than those arrowy spires of our Gothic cathedrals which seem to pierce the very clouds.

Everybody has experienced this disappointment more or less. Its cause is to be found in the massive form of most mountains, in the elevation of the site from which we observe them, in the gradual incline of their declivities, and especially in the complete absence of all standards of comparison. Yet in the Alps, and particularly in the Bernese Alps, there are numerous peaks which escape the general disfavour through their bolder and more precipitous form. Among these may be particularized the Schreckhorn (13,394 feet) and the Finsteraarhorn (14,039 feet). These alone seem to inspire a kind of terror when we contemplate them from the summit of the *col* which separates the Valais from the basin of the Aar.

The traveller who has just ascended the Mayenwand halts involuntarily on the border of the Todten See, or Lake of the Dead (6500 feet), when he discovers the unexpected panorama spread out before him; he forgets the fatigues and the real or imaginary dangers of the Mayenwand, and, in the midst of this sea of mountains, his gaze is irresistibly attracted towards the two colossi, which remind him of the gloomy gods of the German mythology, surrounded by their giants. The one, with a broad, round brow, and an immense black mantle, occupies the centre; the other, more erect, more rigid,

and more unconquerable, with his robe disposed in long folds of silver, stands upon his right: these are the Finsteraarhorn and the Schreckhorn (or Peak of Terror).

It was at the foot of the two giants that, some years ago, we sought a temporary asylum; the Hôtel des Neuchâtelois (7550 feet) is situated, to some extent, on the boundary-line of their domains,—the glacier of the Aar being formed, as we know, of two affluents, one descending from the sides of the Finsteraarhorn, and the other from the sides of the Schreckhorn. During our first sojourn there in 1840, we did not even dream of approaching these formidable ridges. The Finsteraarhorn had been ascended only once—by our guides, Jacob Leuthold and J. Währen, in 1832; and they painted a frightful picture of the difficulties they had had to surmount. M. Hugi, whom they had undertaken to conduct, had been obliged to abandon the attempt when some hundreds of yards from the summit. As for the Schreckhorn, it was reputed inaccessible, and no one had ever attempted to accomplish its ascent.

THE SCHRECKHORN.

In the following year we began to make ourselves more familiar with the difficulties and dangers of mountaineering; and after having accomplished the ascent of the Jungfrau (13,671 feet), were no longer disposed to believe in the inviolability of any peak whatsoever. The

ambition of planting the first flag on the crest of the Schreckhorn,—the only one of the great Bernese peaks which was still virgin, was too natural for us to resist it successfully. It was a fancy, however, which at first we nourished in our minds without giving it positive expression, and which, despite of the stories poured into our ears of the perils of such ascents, continually gained a firmer hold upon us. The discussions which had arisen respecting the nature of the ice in high regions rendered necessary, moreover, a series of new observations; and when we departed on the campaign of 1842, it was with the firm intention of making them on the Schreckhorn.....

We had decided on ascending by the second of the lateral glaciers which lie on your right as you go to the Strahleck; for in this direction the incline of the rock appeared to us less abrupt, and the glacier less broken by crevasses. The uncertainty of the result increased our impatience; we ascended the glacier of the Finsteraar almost at a run, and though it was after seven o'clock when we set out from the Hôtel des Neuchâtelois, we had climbed the *col* of the Strahleck (9750 feet) before ten. The rocky summits of the Schreckhorn and the Lauter-Aarhorns were whitened by a light fall of snow the day before, which caused us some disquiet; for persons accustomed to the mountains know that nothing is so treacherous as fresh snow, which, under a solid appearance, frequently conceals the most terrible precipices. But Jacob reassured us by saying, that as soon as the sun began to shine all this snow would disappear before we had gained the summit.

The glacier we were ascending, though at first very steep, presented a tolerably smooth surface in its upper part, as is the case with all the upper fields of snow; enormous crevasses were excavated in it, but these the snow partially concealed. It is, however, in such localities that the Alpine explorer must use the greatest prudence.

When the crevasse was too broad to be crossed with a leap, we stretched our ladder from side to side like a bridge. Often the stratum of snow which formed the vault or roof of the chasm was a few inches only in thickness; but so long as it masked the opening of the gulf everybody passed over it with perfect confidence; while I doubt very much whether any one would so readily have adventured could we have seen the open crevasse. It is a species of vertigo which we avoid by this means; for, in reality, a thin sheet of paper laid under the ladder would have been quite as effective a support as the stratum of ice.....

The snow which covered the ice was not thick enough to admit of our standing erect upon it, so that our guides, for the greater part of the journey, were compelled to hew out steps with their hatchets. The ice was excessively hard, and could only be detached in flakes and splinters, so that we were not less than two hours in reaching the rock on the other side, after having rested ourselves for a few moments on a small rocky ridge which rose out of the ice at two-thirds of the distance. Above this ridge the declivity is tremendous, and I do not remember to have crossed a more formidable one, except, perhaps, above

the great crevasse in ascending the Jungfrau. Though I was more hardened than in the previous year, this passage of the Schreckhorn nevertheless wrought upon me a much stronger impression than that of the Jungfrau, —undoubtedly because we traversed it obliquely.

The journey was very laborious, but it furnished the material for many interesting observations.

And, first, what struck us most vividly was *the extreme humidity of the ice.* It was between ten and twelve o'clock; the sun was not at its meridian, and yet the quantity of water was so great as to fill immediately the cavities cut with our hatchets; water oozed from all the pores, and even from beneath the ice, when any solution of continuity occurred between it and the rock,—a circumstance which did not fail to incommode us seriously; and as we were obliged to remain almost immovable in this frozen water, I feared for a moment that we might experience some grave inconvenience.

All over the incline the ice was not only much harder than the ice of the *névé*, but also more transparent; and we remarked in its interior a number of spherical or elongated air-bubbles, as in the white ice of the glacier properly so called. Its thickness was not considerable, and what deserves particular notice is, it was not traversed by any crevasse; which confirmed us in the idea that the absence of crevasses is really a feature of the inclined or sloping ice of the high regions (the uppermost ice-wall of the Jungfrau, above the Col de Roththal, does not show the slightest vestige).

When we had gained the rock, we began to think all our difficulties were over: the declivity was certainly, in

some places, much more abrupt; but then, what a difference between placing your foot upon granite and upon ice! It remained for us to determine whether we should or could make a direct ascent, or whether we should reach the summit from the rear; but as the wall of rock which rose before us presented no obstacles, we continued our upward march. Here, in the shadow of a jutting crag, and in a very damp locality, we found some pale ranunculuses (*Ranunculus glacialis*), and their presence in such lofty regions (13,000 feet) interested us greatly.....

We arrived on the summit at about half-past two in the afternoon. The moment of arrival is always a solemn one, when the whole horizon suddenly appears before us, and we cast our first glance around on those peaks and glaciers, which, to some extent, present themselves under an aspect quite different from that they exhibit from below. In this respect it is with mountains almost as it is with intellectual preponderances. Sometimes a genius which we are accustomed to regard as pre-eminent, because it is found in a favourable position, becomes singularly lowered when we examine it from a loftier view-point; while another, which we could scarcely recognize, because it was not in a place to develop itself freely, suddenly assumes a grand and imposing character.....

We spent an hour and a half on the summit. In the presence of so majestic a spectacle, time flies with frightful rapidity. A sigh involuntarily escaped from every breast when Jacob announced to us that we must begin our retreat. He urged it warmly upon us,

and rightly, asserting that we had already remained too long.....

Having reached the upper *col* at half-past four, we found the ice there as moist as at the point where we had traversed it in our ascent. A stone which we hurled on the icy incline glided rapidly to the bottom, and raising the snow as it passed, left behind it a furrow which was almost immediately transformed into an abundant brook. This amplitude of water surprised us all the more that we had hitherto supposed it impossible for water to remain liquid at such an elevation. The majority of observations previously taken on the high mountains by scientific men indicate a temperature below freezing-point. Spite of this, most observers had met with ice even on the loftiest summits. They were therefore led to inquire into its origin, since, for the formation of ice, water is required, and water, in its normal condition, can only exist as water in a temperature above 32°. Last year we had still been much embarrassed in attempting to explain the presence of the ice. Unable to suppose that rain occurred at such tremendous elevations, it was with some hesitation I attributed it to the liquefaction resulting from the influence of the solar rays. Another and very ingenious explanation had been propounded by Rendu, who thought that ice in these upper regions was the product of condensed vapours. Now, since we had found the thermometer mark 32° F. on the summit of the Schreckhorn (13,394 feet), and water form itself abundantly, under the influence of this temperature, at a height of more than 12,500 feet, it was useless to seek any other causes for

the formation of the upper ice than those which are assigned to all glacier ice. It is the snow melting on the surface, under the influence of the solar heat, and the water, penetrating into the inferior strata, which cements them and transforms them into ice, exactly as in lower regions. The only difference is, that there is no *névé* above. So far as this is concerned, the ice of the loftier summits is undoubtedly an exception to the common rule. But this exception is not only proper to the loftier summits; examples of it are also found in less elevated regions, and M. Charles Martins has described several glaciers without *névé* in the chain of the Faulhorn (8800 feet), all whose modifications he has followed up with the greatest care. It is not less worthy of remark that this high summit ice, though formed under circumstances less favourable to the transformation of snow into ice, is much harder, more transparent, and in some sort more perfect, than the *névé* ice below. This is due, probably, to its lesser density, which permits the surface-water to propagate itself more uniformly in every stratum. The same reason undoubtedly prevents it from crevassing, as the ice in the bottom of the valleys does. And then, we must not lose sight of the fact that, if these high regions have a temperature lower than that of the valleys, they are more exposed, on the other hand, to the rays of the sun and the action of warm winds,—especially of the föhn, which often blows only on the Alpine summits.....

When we had reached the level of the point where in the morning we had traversed the wall of ice, we kept to the right, and crossing a last patch of ice, con-

tinued our descent along the ridge, without encountering any obstacle. At nightfall we arrived upon the glacier. One of the guides, whom we had sent in advance to recover the ladder left behind in the snow-fields, was there half an hour before us, and assured us he had not met with any difficulty; for when he had gained the last snowy incline, he had got astride his ladder, and glided down to the bottom. From this point we had still fully a couple of leagues (French) to accomplish to reach the Hôtel des Neuchâtelois; but, though night-travelling on the glaciers is anything but agreeable, we were not the least disturbed, —we were passing through a country perfectly familiar to us.

The worst evil of these night-journeys is the *ennui* they cause; for, to avoid falling into the crevasses, we must keep the pupil stretched, and the eye constantly fixed on the spot where we are going to plant our foot. To travel for two hours in this fashion without being able to converse, without being able even to think, is assuredly wearisome. I need not say, then, that it was with singular satisfaction we caught sight, in doubling the Abschwung, of the lights of the Hôtel des Neuchâtelois, which had a strange and eëry effect in the midst of the sea of ice. Our friends heard with still livelier joy the first shouts of our guides. Immediately they sent two men with a lantern to meet us, and some wine to recruit our energies. About ten o'clock we arrived at the Hôtel, somewhat fatigued, but fortunate in having one fine day the more to register among our souvenirs of the Alps.*

* E. Desor, *Revue Suisse*, June 1843.

WINTER EXPEDITION TO THE MER DE GLACE OF MONT BLANC.

By Professor Tyndall—December 27, 1859.

A chapter with the above title is one of the most exciting portions of Professor Tyndall's book on the Alpine glaciers. As the book is accessible to most of our readers—who will find it, we may add, far more exciting than any sensational romance—our quotations from it will be very brief.

After five hours and a half of hard work, the professor and his party reached the Montanvert. The sight of the little auberge at this point was very welcome, though the wind had carried away its snow buttresses, piling the mass thus displaced against the adjacent sheds, to the roofs of which one might step from the surface of the snow.

"In the application of her own principles," says Professor Tyndall, "Nature often transcends the human imagination; her acts are bolder than our predictions. It is thus with the motion of glaciers; it was thus at the Montanvert on the day now referred to. The floors, even where the windows appeared well closed, were covered with a thin layer of fine snow; and some of the mattresses in the bedrooms were coated to the depth of half an inch with this fine powder. Given a chink through which the finest dust can pass, dry snow appears competent to make its way through the same fissure. It had also been beaten against the windows, and clung there like a ribbed drapery. In one case an effect so singular was exhibited, that I doubted my eyes when I first saw

it. In front of a large pane of glass, and quite detached from it, save at its upper edge, was a festooned curtain formed entirely of minute ice-crystals. It appeared to be as fine as muslin; the ease of its curve and the depth of its folds being such as could not be excelled by the intentional arrangement of ordinary gauze. The frost-figures on some of the window-panes were also of the most extraordinary character; in some cases they extended over large spaces, and presented the appearance which we often observe in London; but on other panes they occurred in detached clusters or in single flowers, these grouping themselves together to form miniature bouquets of inimitable beauty. I placed my warm hand against a pane which was covered by the crystallization, and melted the frostwork which clung to it. I then withdrew my hand, and looked at the film of liquid through a pocket lens. The glass cooled by contact with the air, and after a time the film commenced to move at one of its edges; atom closed with atom, and the motion ran in living lines through the pellicle, until finally the entire film presented the beauty and delicacy of an organism. The connection between such objects and what we are accustomed to call the feelings may not be manifest; but it is nevertheless true that, besides appealing to the pure intellect of man, these exquisite productions can also gladden his heart and moisten his eyes.

"The glacier excited the admiration of us all: not as in summer, shrunk and sullied like a spent reptile, steaming under the influence of the sun; its frozen muscles were compact,—strength and beauty were associated in its aspect. At some places it was pure and smooth; at

others frozen fins arose from it, high, steep, and sharply crested. Down the opposite mountain-side arrested streams set themselves erect in successive terraces, the

THE MER DE GLACE OF MONT BLANC, SEEN FROM MONTANVERT.

fronts of which were fluted pillars of ice. There was no sound of water; even the Nant Blanc, which gushes from a spring, and which some describe as permanent through-

out the winter, showed no trace of existence. From the Montanvert to Trélaporte the Mer de Glace was all in shadow; but the sunbeams, pouring down the corridor of the Géant, ruled a beam of light across the glacier at its upper portion, smote the base of the Aiguille du Moine, and flooded the mountain with glory to its crest. At the opposite side of the valley was the Aiguille du Dru, with a banneret of snow streaming from its mighty cone. The Grande Jorasse, and the range of summits between it and the Aiguille du Géant, were all in view; and the Charmoz raised its precipitous cliffs to the right, and pierced with its splinter-like pinnacles the clear cold air. As the night drew on, the mountains seemed to close in upon us; and on looking out before retiring to rest, a scene so solemn had never before presented itself to my eyes or affected my imagination."

An Alpine hurricane broke out upon the Mer de Glace. Its features are thus described by Professor Tyndall:—

"The wind rose during the night, and in the morning a series of clouds had ranged themselves along the ridge of cliffs which terminates the Glacier de Léchaud. The portion of the heavens behind the ridge was near the domain of the rising sun, and when he cleared the horizon his red light fell upon the clouds, and ignited them to ruddy flames. Some of the lighted clouds doubled round the summit of the mountain, and swathed its black crags with a vestment of transparent red. The adjacent sky wore a strange and supernatural air; indeed, there was something in the whole scene which

HURRICANE ON THE MER DE GLACE.

baffled analysis, and the words of Tennyson rose to my lips as I gazed upon it,—

'God made himself an awful rose of dawn.'

"The cloud-flag which the wind wafted from the summit of the Aiguille du Dru reached extraordinary dimensions. It was brindled in some places as if whipped into curls by the wind; but through these, continuous streams were drawn, which were bent into sinuosities resembling a waving flag at a mast-head. All this was now illuminated with the sun's red rays, which also fringed with fire the exposed edges and pinnacles both of the Aiguille du Dru and the Aiguille Verte. Thus rising out of the shade of the valley the mountains burned like a pair of torches, the flames of which were blown half a mile through the air. Soon afterwards the summits of the Aiguilles Rouges were illuminated, and day declared itself openly among the mountains.....

"The air darkened; angry clouds gathered round the mountains, and at times the glacier was swept by wild squalls. The men were sometimes hidden from me by the clouds of snow which enveloped them, but between these intermittent gusts there were intervals of repose, which enabled us to prosecute our work. This line was more difficult than the first one; the glacier was broken into sharp-edged chasms; the ridges to be climbed were steep, and the snow which filled the depressions profound.....

"The evening became wilder, and the storm rose at times to a hurricane. On the more level portions of the

glacier the snow lay deep and unsheltered; among its frozen waves, and upon its more dislocated portions, it had been partially engulfed, and the residue was more or less in shelter. Over the former spaces dense clouds of snow rose, whirling in the air and cutting off all view of the glacier. The whole length of the Mer de Glace was thus divided into clear and cloudy segments, and presented an aspect of wild and wonderful turmoil. A large pine stood near me, with its lowest branch spread out upon the surface of the snow; on this branch I seated myself, and, sheltered by the trunk, waited until I saw my men in safety. The wind caught the branches of the trees, shook down their loads of snow, and tossed it wildly in the air. Every mountain gave a quota to the storm. The scene was one of most impressive grandeur, and the moan of the adjacent pines chimed in noble harmony with the picture which addressed the eyes."

The storm continued on the following day, and the fall was so thick that Professor Tyndall could not see the men he had set at work upon certain measurements. Some time afterwards, the air became perfectly still, and the snow underwent a wonderful change. Frozen flowers, similar to those observed on Monte Rosa, fell in myriads. For a long time, says Professor Tyndall, the flakes were wholly composed of these exquisite blossoms entangled together. And thus prodigal Nature rained down beauty, and had done so here for ages unseen by man. And yet some flatter themselves with the idea that this world was planned with strict reference to human use; that the lilies of the field exist simply to appeal to the sense of the beautiful in man. True, this result is secured, but it

SOURCE OF THE ARVEIRON.

is one of a thousand all equally important in the eyes of Nature. Whence came those frozen blossoms? Why have they been for ages wasted? The question reminds us of the poet's answer when asked to explain the origin of the rhodora :—

> "Why wert thou there, O rival of the rose?
> I never thought to ask, I never knew;
> But in my simple ignorance suppose
> The self-same Power that brought me there brought *you!*"
>
> EMERSON.

We shall finally attempt a description, assisted by the same great authority, of the source of the river Arveiron :—

The quantity of water which issues from the vault at the foot of Mont Blanc is considerable, and its character that of true glacier water. In autumn it is still turbid with suspended matter; but not so turbid as in summer. The difference in force and quantity will probably account, however, for the greater summer turbidity.

This character of the water can be due only to the grinding motion of the glacier upon its bed; a motion which does not seem to be suspended even in the depths of winter. The temperature of the water, on the occasion of Tyndall's visit, was the tenth of a degree Centigrade above zero; that of the ice, half a degree below zero. This was also the temperature of the air, while that of the snow, which in some places covered the ice-blocks, was one degree and a quarter below zero.

The entrance to the vault was formed by an arch of ice which had detached itself from the general mass of the glacier behind: between them was a space through which we could look to the sky above. Beyond this the

cave narrowed, and the traveller found himself steeped in the blue gleam of the ice. The roof of the inner arch was perforated at one place by a shaft about a yard wide, which ran vertically to the surface of the glacier. Water had run down by the sides of this shaft, and, being re-frozen below, had formed a composite pillar of icicles at least twenty feet high, and a yard thick, extending from floor to roof. They were all united to a common surface at one side, but at the other they formed a series of flutings of exceeding beauty.

AN ICE-CAVE.

This group of columns was bent at its base, as if it had yielded to the forward movement of the glacier, or to the weight of the arch overhead. Passing over a number of large ice-blocks which partially filled the interior of the vault, the traveller reached its extremity, and here found a sloping passage with a beautiful, perfect crystal arch overhead, and leading by a steep ascent to the upper air. This singular fairy-like gallery was about seventy feet long, and floored with snow. Creeping up it, you can descend by a slide to the frontal portion of the cavern. "To me," adds Professor Tyndall, "this crystal cave, with the blue light glistening from its walls, presented an aspect of magical beauty. My delight, however, was tame compared with that of my companions."

BOOK II.

AVALANCHES, ICEBERGS, AND ICE-FIELDS.

I.

Avalanches.

"Hoar Mount! with thy sky-pointing peaks,
Oft from whose feet the avalanche, unheard,
Shoots downward, glittering through the pure serene,
Into the depth of clouds that veil thy breast."

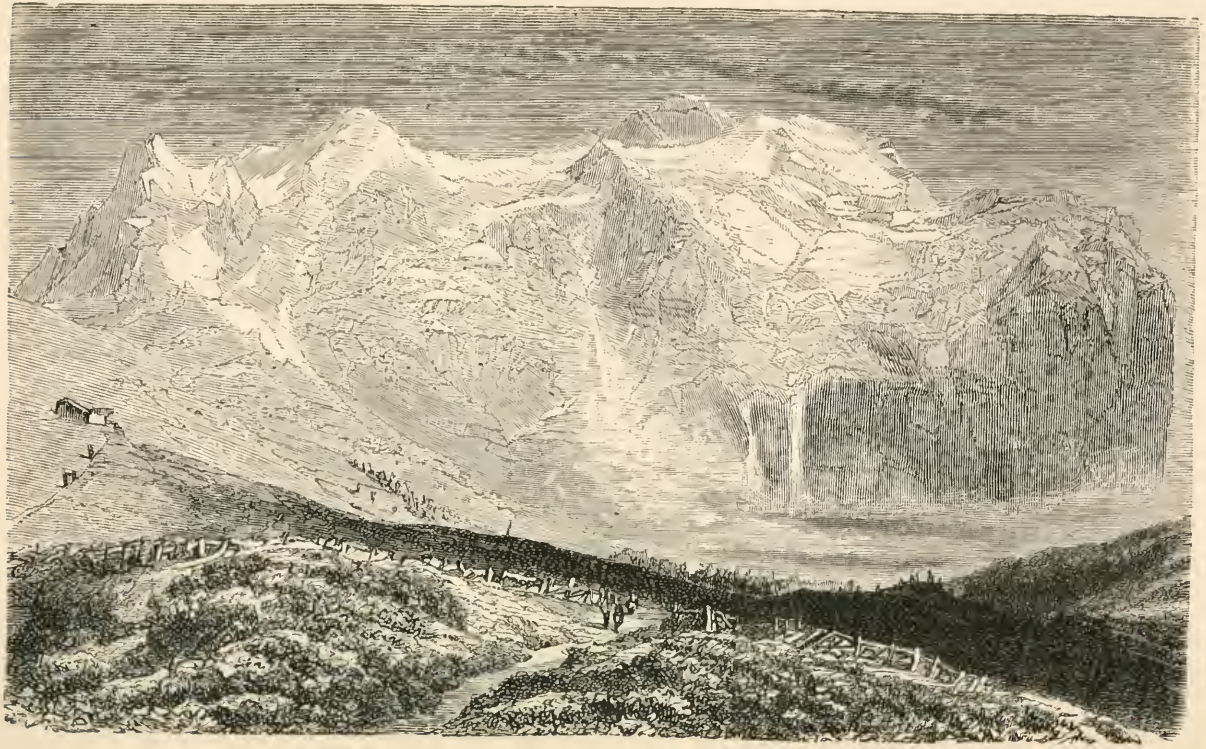
COLERIDGE.

AVALANCHES are among the grandest and most formidable of the phenomena of the Ice-world. They are huge masses of ice and snow which crash and sweep down the declivities of lofty mountains, overthrowing every obstacle they encounter,—woods and villages,—and frequently effecting the most terrible destruction. They generally occur in autumn, and with so much suddenness that neither men nor cattle, in many cases, are able to escape from their range, but are buried beneath them, or beneath the earth, rocks, and trees they

carry along with them in their tremendous course. Sometimes they are caused by the immense weight of the accumulated snow and ice; sometimes by the melting of the mountain-snows, when the under-soil becomes loose and slippery, and, detaching itself from its place, glides down the declivity with constantly increasing swiftness. Then there are the *Staub Lawinen*, Drift or Powder Avalanches: these consist of snow, which, rendered loose and dry by a long frost, is set in motion by the wind, gathers in mass and impetus as it descends, and bursts suddenly on the plain or valley in one vast and overwhelming cloud of dust.

In Switzerland avalanches of a remarkable character are of common occurrence. A recent traveller describes one which he saw on the Jungfrau, in the following graphic terms :—

We undertook our visit to the glaciers of Switzerland in the middle of summer, a season when avalanches are seldom dangerous; so that this formidable word does but recall to us the magnificent spectacle we witnessed in our route along the Scheideck, in front of the noble Jungfrau, the virgin Alp, whose beautiful white summit remained for so long a period inaccessible to the boldest explorers. This portion of our journey occupied scarcely an hour, and yet twice in that time our guide exclaimed, "Look at the avalanche!" pointing to a simple thread of silver on the loftiest rocky declivities of the mountain. We followed with a lively curiosity the development of the phenomenon. The cascade rebounded suddenly, raised a thick cloud of white dust, and gave birth to other and larger cascades, which descended from stage to stage even to the



THE JUNGFRAU.

base, covering the latter over a very considerable area. During the fall of these impetuous torrents of snow and ice we heard continued rollings and crashes like peals of thunder, which were long repeated by the numerous echoes of the valleys of Grindelwald and Lauterbrunnen.

Too often, unfortunately, avalanches are the most terrible scourges of mountainous countries. Farms, and villages, and forests are swept away, as we have said, in their headlong movement; and in descending to the bottom of the gorge or valley they spread the most terrible devastation around them by blocking up the streams and water-courses, which are thus made to overflow in wide-spread inundations.

We shall now proceed to indicate the principal characteristics of the three kinds of avalanches distinguished by our physicists,—the Ground-avalanches (Grundlawinen), Ice-avalanches, and Wind-avalanches.

GRUNDLAWINEN: GROUND-AVALANCHES.

When the thaw commences in the spring, the snow melts very unequally in the upper regions of the mountains. Necessarily, it first disappears from the slopes most exposed to the sun. Deep-coloured rocks or earths grow warm very rapidly, and stimulate the process of fusion around them over an extensive area. On reaching the snow-field, the water thus produced does not remain on the surface, but percolates and filters to the soil below, where, by gliding between the snow and the earth, it slowly makes its way to the steeper inclines. Its temperature being some degrees above freezing-point, it

slowly melts the lower strata of the snowy mass, and thus detaching it from the soil, facilitates its downward motion by the impulse derived from its own weight.

Such is the origin of what are called, by the German physicists, *ground-avalanches.*

They prove most dangerous at the bottom of great declivities, especially when the warm breath of the *fœhn*, or south-east wind, blows up from the lands of the south.

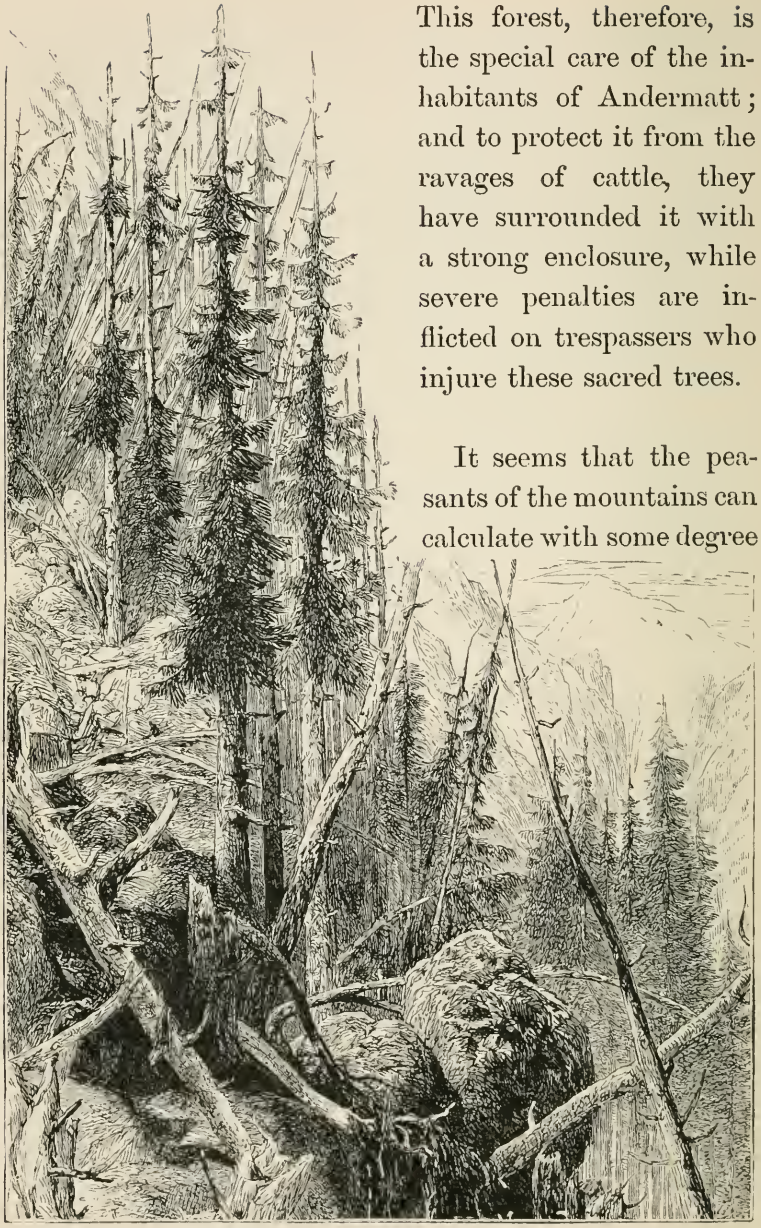
In the opening days of March, says Ramond, this wind suddenly changes the temperature, enamels the meadows with blue violets, and bestows on those who inhale it the first feeling of spring. But as soon as it has swept across the Alpine summits, the avalanches succeed one another uninterruptedly, torrents burst forth from every glacier, and the rivers, suddenly swollen, overflow their banks. By degrees, as the season advances, this violent action ceases; all the snow-masses capable of being detached have fallen, so that in summer their descent is of very rare occurrence.

In numerous localities ground-avalanches are periodical. As the same conditions annually recur, they fall every year at exactly the same epoch, and, consequently, are easily avoided. The people of Tavetset are in the habit, as soon as summer arrives, of planting barriers of fascines across the route of any impending avalanches; and, owing to the resistance thus opposed to the course of the snowy masses, they secure sufficient time to shelter themselves and their flocks.

Frequently, a slight undulation or projection of the soil will be sufficient to arrest or turn aside an avalanche.

A GROUND-AVALANCHE.

The village of Andermatt, which lies at the foot of Mount St. Gothard, owes its preservation to a small forest of venerable firs situated on the declivity that overhangs it.



This forest, therefore, is the special care of the inhabitants of Andermatt; and to protect it from the ravages of cattle, they have surrounded it with a strong enclosure, while severe penalties are inflicted on trespassers who injure these sacred trees.

It seems that the peasants of the mountains can calculate with some degree

of exactness the time required by a ground-avalanche to break loose from the slope on which it is reposing. Their knowledge of the temperature of the upper regions, on which the fall more particularly depends, is obtained from well-understood signs,—such as the transparency of the air, the form and direction of the clouds, and the appearance of the snow as it lies on the ledges or in the fissures of the rocks. But when the winds have accumulated the snow at particular points, and violent atmospheric disturbances contribute to affect the equilibrium, their forecasts are necessarily uncertain; and travellers, in crossing the Alpine passes, are then compelled to trust to the ordinary maxims of prudence. Thus, they should always separate into several groups when traversing a dangerous locality, keeping at such a distance that, in case of a calamity, those who escape being drawn into it may be able to carry assistance to the less fortunate. They should set out in the early morning, before the sun's rays have had much power on the snowy peaks; and they must carefully avoid any sounds or noises capable of perceptibly agitating the air as high as the snowy region. Before entering a defile, moreover, they should discharge their firearms, in order to accelerate any falls which may be immediately impending.

These precautions, of course, are necessary only in the dangerous season.

In the deeper gorges are frequently accumulated by the end of summer immense masses of snow deposited by the avalanches, which the summer warmth has proved inadequate to melt. If this accumulation should extend, as it sometimes does, from side to side of the valley, the

torrent rolling in the valley-bottom will be stayed in its course. The waters, however, soon contrive to force a passage through the lower strata of the snow-barrier, and the latter then remains above them, suspended like an arcade, and forming a natural bridge, frequently of great assistance to the hardy explorer.

To these grave disasters directly produced by the fall of the ground-avalanches, such as houses shattered or swept away, and men and cattle buried alive, of which the annals of all mountainous districts record but too many examples, must be added the havoc caused by the column of air which they drive before them, frequently with an irresistible force.

We may illustrate this statement by a true record.

In 1844, an avalanche crashed headlong down the flanks of the Prarion, at no great distance from the valley of Chamounix. During its descent it did no other damage than level a number of trees, and it halted at the bottom of the gorge which skirts the foot of the mountain. But, on the opposite declivity, at an elevation of 60 or 70 feet higher, and at a distance of 1300 feet, several firs were overthrown by the furious wind resulting from the movement of the avalanche. It was evident that the mass of soft and non-elastic snow, of which it was composed, had been unable to make its way up so considerable an incline as the adverse mountain-slope; but it had effected a violent atmospheric concussion.

The history of avalanches is full of moving narratives, of touching and pathetic incidents. From these we

select one of an extraordinary character, which is recorded in an old Swiss chronicle :—

"The chevalier Gaspard de Brandenburg, of Zug, a lieutenant-colonel in the Spanish service, descended the St. Gothard into the Levantine valley, accompanied by a servant. It was spring, and they had arrived at a point near Aïrolo, when both were suddenly buried under an immense avalanche let loose from the Alps which bordered their road. A little dog that followed them—but at the moment of the calamity was some distance in the rear—escaped their melancholy fate. Perplexed by their disappearance, and probably finding all efforts to discover them useless, it returned to the Hospice of St. Gothard, where its master had spent the preceding night.

"He barked, and leaped round about the residents, as if to implore them to follow him, and afterwards took anew the road to the valley. But at first he obtained no attention. It was not until the following day, after watching his journeys to and fro, and his repeated solicitations, that the people of the hospice suspected some disaster had occurred, and allowed the poor dog to conduct them to the scene of his master's disappearance. On coming within view of the recent avalanche, they began to understand his urgency. They went in quest of the necessary tools, and after long and painful toil discovered the two poor wretches, who had passed six-and-thirty hours under the snow, and who, under God's mercy, owed their lives to the fidelity and intelligence of the chevalier's dog.

"In their cold, dark prison they had awaited with indescribable agony a death as slow as it was painful, and

had no hope of safety until they heard the voices and efforts of their deliverers; for the snow, though compact enough to prevent them from effecting their escape, permitted the sound to reach them of those who had so opportunely come to their assistance. We say opportunely, for they could not have endured much longer the want of food and the misery of their position.

"There is still to be seen at Zug, in the church of St. Oswald, and on the tomb of the chevalier, who died in 1528, a statue, executed by his orders, representing him with his faithful spaniel at his feet."

AVALANCHES OF ICE.

When the progressive movement of the glaciers, instead of carrying their emissaries, the avalanches, by gentle inclines into the temperate region, accumulates them on the brink of steep escarpments, they remain suspended for some time above the precipices, like an overhanging roof. The impending mass continually increasing, its solidity soon ceases to be in equilibrium with its weight; it breaks up and falls in numerous fragments into the valley, which resounds with the din of each headlong shock.

In the valley of Zermatt, the village of Rauda is dominated by the glittering pyramid of the Weisshorn,—which owes its name to the purity of its snow,—and by its abrupt inclination, about 40°, justly terrifies the travellers who pass at its foot. In 1819, an enormous portion of its glacier was detached, and fell headlong. And so violent was the fall, that nearly all the houses of Rauda, which, according to the custom of the country, were erected upon

AN ICE-AVALANCHE.

piles, were prostrated, not by the shock of the mass of ice, but by the air it displaced and drove before it. The avalanche itself was arrested in a locality separated from the village by a large stream.

The accumulation of ice at the bottom of valleys is far more dangerous than that of snow, because the latter melts with some rapidity when brought in contact with the water of the torrents. This accumulation is sometimes the cause, for instance, of terrible inundations. In the spring of 1818, numerous avalanches detached from the glacier of Gétroz had descended into the valley of Bagnes, which is one of the principal ramifications of that of the Rhone. They formed a secondary glacier, which barred the torrent of the Dranse, and the waters, gathering swiftly behind this natural embankment, created a lake of some 8000 feet in length, and over 650 feet in breadth. A mass of thirty millions of cubic yards was suspended above the lower part of the valley, and the inhabitants were thrown into a panic of terror. An engineer of the Valais, M. Venetz, resolved to provide the waters with a means of gradual distribution, and caused a gallery or tunnel to be excavated in the ice at a sufficient distance below the level of the lake. This tunnel was nearly 300 yards in length. It had carried off about a third of the contents of the lake, when, on the 16th of June, after a succession of very warm days, the whole range of the dyke began to give way : the torrent opened up suddenly a new channel, and advanced towards the valley, in a flood 140 feet high, and at a rate of twelve French leagues per hour. It carried down with it enormous rocks, a

part of the forest, and upwards of a hundred châlets. The inhabitants, with their cattle, took refuge on the heights, and had to regret but a small number of victims; all the country, however, was desolated and covered with stones. The town of Martigny, situated on the bank of the Rhone, some 22 miles from the glacier (30 kilomètres), suffered severely; the water in its streets rose to a height of ten feet. The impetuosity of this deluge did not diminish until it reached the broader valley of the Rhone.

M. Venetz has recommended a means as simple as ingenious of preventing the formation of a new embankment of ice of such huge dimensions. During the summer season it will be sufficient to direct upon the secondary glacier the numerous springs which issue from the slopes of the valley. The temperature of their waters rises considerably as they flow over rocks warmed by the sun; and when, by means of trenches, they have been brought to bear on every point of the glacier, their heat, combined with that of the atmosphere, melts a very great quantity of ice, and so prevents the dyke from attaining such a height as to block up the channel of the torrent. In winter, secondary glaciers do not increase very largely; and the Dranse, like all Alpine torrents, being very low, these precautions are not necessary.

In the Alps there are many glaciers which precipitate themselves, like avalanches, upon other glaciers. From the eastern side of the Eiger, a cascade of ice descends upon the lower glacier of Grindelwald. Not far from Cormayeur, to the south of Mont Blanc, you see the glacier of La Brenva descend in an avalanche, as it were,

upon itself, at the point where it is compelled to double a great escarpment. After their fall, the great blocks of ice accumulate in a triangular sloping "landslip," incessantly modified by the movement of the glacier on which it rests. In making the ascent of this mountain, it is necessary to pass with a run over the narrow plain known as the Petit Plateau; where avalanches of broken ice frequently fall from the height of the escarpments which dominate it, and are shattered into a thousand fragments: according to M. Charles Martins, who sojourned for a long time near this dangerous locality, one of these falls occurs nearly every hour.

WIND-AVALANCHES.

The wind-avalanche is the phenomenon which most closely brings the Alps into approximation with the northern regions of the globe. It is a displacement of the snows occasioned by the violent storms of winter. Preserved by the cold in their naturally light condition, they are transported to very great distances, and frequently accumulate to the size of actual hills. The whole aspect of the country-side is changed in a moment. The paths traced out by frequent footsteps disappear; the sign-posts, raised at intervals to indicate the direction of the routes, are prostrated; and if the unfortunate traveller be not overwhelmed under this furious sea, he casts his eyes with a feeling of desolation over a uniform plain where no landmark guides his steps.

Wind-avalanches become especially terrible during the very low temperatures of winter. The snow, as pulverulent then as the sand of the deserts, is frequently carried

away, like that sand, in immense whirling clouds. Villages, and large companies of men, have been thus covered, in a moment, with a deep stratum. The Swiss chronicles speak of sixty soldiers who disappeared under an avalanche in 1478. In 1500, another avalanche buried, at the pass of the Great St. Bernard, a hundred individuals.

On the 14th of January 1719, the whole village of Leukerbad, with the exception of a few huts, was covered with a mass of snow so dense that only a few inhabitants escaped; and these, with great difficulty, forced a passage through it. It is recorded that a young lad remained buried for a whole week at the bottom of a cavern, after vain attempts to release himself with his feeble arms. Wearied by his efforts, he began to sing all the psalms he was acquainted with, and his voice so clearly penetrated the thickness of the frozen stratum that it was heard by some passers-by, who hastened to the poor child's rescue.

In the month of February, in the year following, one hundred and twenty houses and stables, with eighty-four men, and a great number of cattle, were destroyed by an avalanche at Obergestelen, in the Valais. In March, the snow swallowed up sixty-one men at Tethan, in the Lower Engadine.

In 1749, the village of Ruaras, in the canton of the Grisons, was almost entirely covered by an avalanche which fell upon it during the night. A hundred persons were buried; sixty only succeeded in effecting their escape from their prison of snow. A similar event took place at Biel, in the Valais, in 1827, when thirty men were killed.

How many travellers have been engulfed in wind-

THE HOSPICE OF MOUNT ST. BERNARD.

avalanches in the lofty passes of the Alps! Happily, the spirit of Christian devotion has guided into the heart of these frozen solitudes companies of religious men,—of monks who on stormy days traverse them in all directions, and seek to rescue the victims from death. They have founded fifteen places of refuge. The principal is the Hospice of St. Bernard, the most elevated habitation in Europe, in the vicinity of which upwards of ten thousand persons pass every year. The service is most admirably organized, and the monks are powerfully assisted in their explorations by a particular species of dogs which possess a remarkable instinct for recovering the traces of travellers.

MELTING OF SNOW UPON VOLCANOES, AND CONSEQUENT FLOODS—ICE BENEATH LAVA.

With avalanches we must connect the great floods which have sometimes occurred on the declivities of very lofty volcanic mountains, such as those of the chain of the Andes. Before the eruptions commence, the interior heat communicated to the lavas, and afterwards to the snows of the summit, cause the water of the thaw to trickle between the ground and the lower strata, which are thereby loosened, glide down the slopes, and rush headlong to the volcano's base. These avalanches announce, therefore, the approaching explosion of the subterranean fires. The flood increases in proportion as the outpourings of the crater accelerate the fusion of the icy stratum, and formidable inundations are frequently produced by torrents which carry along with their foaming waters smoking scoriæ and blocks of ice.

It sometimes happens that the reaction of the igneous

products of the volcano on the ice-masses of its slopes presents a phenomenon entirely different from that which we have described. Upon Etna, for example, a stratum of ice has been preserved for centuries between two strata of lava. At the first glance, the thing appears difficult to believe: water and fire in so close a union! The ice maintaining the fire; the fire preventing the ice from melting. How could we expect to meet with ice beneath the currents poured forth from the entrails of a volcano?

The origin of this singular discovery was as follows:—

In 1828, the summer heat had been so great that the stores of ice at Catania were exhausted; it was wanting everywhere throughout Sicily, and Malta had sent for a supply without being able to procure it at any price. In these countries ice is not, as with us, a simple object of luxury or daintiness, but a general want, which everybody experiences daily. People would rather see all the caves dried up than the ice-houses empty. It even appears that, for hygienic reasons, cool drinks are needful, and that the public health would be endangered if these could not be obtained. You may easily understand then into what distress all Sicily was plunged by its unexpected and most lamentable ice-famine.

In this crisis the magistrates of Catania addressed themselves to M. Gemellaro, one of the most assiduous and scientific explorers of Mount Etna, hoping that his intimate knowledge of its localities might be able to point out some crevasse or grotto in which an unknown reserve of ice or snow might have accumulated. Geology found itself invoked, in the person of M. Gemellaro, to render

to society an entirely novel kind of service, the importance of which, spite of its originality, it was certainly impossible to contest.

By a fortunate chance, our geologist was able to respond to the demand made upon him. He had long before observed on the summit of Etna, among the ashes and scoriæ, the edge of a small block of ice exposing itself to the light: various circumstances had led him to suspect that this was but the sign of a much thicker stratum of ice, which in earlier times had been covered by lava during an eruption.

Taking with him a body of workmen, he repaired to the spot, opened up the rock with pick-axes, excavated some galleries, and arrived at length at a thick stratum of ice, confined by lava in all directions, and of sufficient extent to satisfy amply the wants of the town.

Now for an explanation of the fact; it is very simple. In winter, owing to the great elevation of Etna, a quantity of ice and snow accumulates around its summit, which, afterwards, the volcanic heat almost wholly melts. They remain only in chinks and crevasses protected from the rays of the sun. It is easy to understand that, the volcano not being always in activity, its summit may become as cold as that of any other mountain of the same elevation. Now, let us imagine that while the upper part of the mountain is thus enveloped with a hood of ice, an eruption occurs: a column of ashes rises, is partially cooled during its ascent, then falls back upon the ice, gradually covers it with drift, accumulates there, and forms a stratum of varying thickness over its whole extent: the sole effect produced is to determine the fusion

of a small quantity of ice, which, damping the lower part of the stratum of cinders, eventually cools it. Let the volcano, continuing the course of its ejections, now vomit through its crater floods of lava,—this lava descends towards the part of the mountain where but just before winter prevailed, and which a crust of ice covered; but the ice, under its protecting stratum of cinders, remains sheltered from the fire; the heat either does not penetrate, or penetrates very slightly to it; under its mantle of lava it remains intact; gradually this mantle grows cold, solidifies, assumes the temperature common to the upper regions of Etna, while the ice, inaccessible to its influence, and constantly preserved from it by the sun's rays, remains fixed and unalterable.

The peasants who inhabit the elevated rocks of Etna are accustomed, in order to preserve the snow destined to water their flocks during the summer, to spread over its surface, just at the close of winter, a stratum of ashes sufficient to protect it from the action of the solar rays, and to preserve it for their wants as long as they please. M. Gemellaro had undoubtedly taken note of this practice, and by generalizing from it succeeded in divining and discovering the existence of the precious and singular ice-store we have just described. The ignorant man is content with observing; the wise man not only observes, but incessantly labours to compare his observations and to derive just conclusions from them.

II.

Floating Ice.

PRODUCTION OF ICE AND FORMATION OF CREVASSES ON THE SURFACE OF LAKES.

PROFESSOR DEICHE has given to the world some very curious observations on the manner in which ice is formed on the surface of the great lakes, and on the crevasses produced in these masses of congelated water.

We have already said that the ice presents a variable structure, and that, as a general rule, it possesses a laminated or granular texture. When the water in a fresh-water basin safe from all agitation freezes, you will see numerous icicles forming near its margin, which join together and produce large patches; and these, joining in their turn, spread over the whole surface a crust of ice.

In salt water, the dissolved salts separate under the influence of congelation, which begins by the production of floating blocks of ice, whose union forms an ice-bank or ice-floe. Congelation takes place under analogous conditions in the midst of fresh-water lakes, when violently agitated. The frozen surface is then covered with ruggednesses, though it is smooth if formed in the midst of a calm. After a thaw, the ice of rivers, streams, or seas,

instead of breaking up into grains like the ice of glaciers, is dissolved into fragments of various sizes.

During the severe winter of 1860–61, the lakes of Switzerland were covered for nearly two months—from January to March—with a thick stratum of ice. M. Deiche profited by this exceptional opportunity to study, on the lake of Untersee, the crevasses and fissures of the ice. These two kinds of cleavage differ as follows: in the fissures, which are narrower and shorter, the surfaces of the separated parts preserve the same height; while in the crevasses, the dimensions of which are always very considerable, they are situated at unequal elevations. The direction of the crevasses is nearly always parallel to the longitudinal axis of the lake; this is not the case in fissures, which spread in every direction. The violent disruptions by which these solutions of continuity are produced are, for the most part, accompanied by a movement of the frozen surface similar to the vibrations of slight earthquakes, and, at the same time, you may hear below the surface the roar, as it were, of a storm mingled with hoarse detonations. In cold nights, and especially when the crevasses are freezing again, these sounds are also heard. M. Deiche refers to the following examples :—

A CREVASSE ON A LAKE.

On the 28th of January 1861, the phenomenon reached

its maximum of intensity. The thunder-claps, the hissings, the rattlings, were prolonged for nearly twelve hours; the air was calm, and a deep fog prevailed. The old crevasses had been reclosed by the frost, and the noise did not cease until the surface separated in divers parts, and allowed the water a free passage.

On the 1st and 2nd of February, between 8 and 10 A.M., a violent noise was again heard, accompanied by roaring sounds underneath the ice. On the 3rd and 5th, similar noises were simultaneously produced on the lakes of Zeller, Mündel, and Markelfinger.

These phenomena generally occur at the same time as the temperature declines, and are always manifested where the crevasses are closed by the frost. The fishermen and boatmen designate these crevasses "wounds in the ice;" and when the water is forced to the surface, they say *the ice bleeds*. They attribute the movements and detonations we have just described to the expansion of the ice, and to the currents of air established beneath it—the water having need, like a living body (according to them), of air for its nourishment.

This prejudice finds a starting-point in the phenomena of the respiratory action among aquatic animals, which, in the performance of this action, consume a good deal of oxygen, and expire carbonic acid and azote. The water being unable to dissolve the whole of these irrespirable gases, which find no issue in the interior surface of the ice, produce through their accumulation the vibrations and violent noises which precede or accompany the appearance of the crevasses. In regions where the absorption of air and expulsion of gases are partly effected by a current,

crevasses are not produced; but the fishers then make openings in the ice, thinking them needful to prevent the fish from suffering.

To conclude: M. Deiche, in his explanation of the traditional prejudices transmitted among fishermen on the necessity of crevasses, thinks we should attribute to changes of temperature, and the action of compressed gases, those disruptions of the surface-ice of our lakes which serve to re-establish the equilibrium destroyed by the congelation of their surface.

SEVERE WINTERS—RESISTANCE OF THE ICE.

In very severe winters, the thickness of the ice on the surface of inland seas, lakes, and rivers, is found sufficient to support the greatest burdens. We shall cite some examples of this resistance, due to excessive frosts :—

In the year 400, the Black Sea was entirely frozen over.

In 821, chariots heavily laden could cross the Danube, the Elbe, and the Seine upon the ice for upwards of a month.

859.—In this year the Adriatic Sea was frozen so hard that persons on foot could pass from the mainland to Venice.

1325.—Pedestrians, as well as horsemen, travelled upon the ice from Denmark to Lubeck and Dantzig.

1458.—The river Danube was frozen from bank to bank, and an army of forty thousand men encamped upon the solid surface.

1657.—Charles X., King of Sweden, he who

> "Left a name at which the world grew pale,
> To point a moral and adorn a tale,"

carried across the frozen strait, from Fionia to Zeeland, all his army, artillery, cavalry, powder-waggons, tents, cars, and heavy baggage.

1740.—The Thames was frozen over. The people of the metropolis constructed a spacious kitchen on the ice, and roasted a whole ox. Coaches plied upon the river.

1765-66.—A terrible frost, productive of much distress, lasted from

December 25, 1765, to January 16, 1766, and from January 18 to January 22.

1789.—The Thames could be crossed on foot, or in carriages, opposite the Custom House.

1794-95.—A frost broke out on December 24, 1794, and endured until February 14, 1795, with only the intermission of one day's thaw (January 23rd). It was extraordinarily severe, and seems to have extended over nearly all Europe.

1812.—Terrible frost in Russia. It was in this memorable winter that Napoleon's army perished, on its retreat from Moscow. The men fell dead by hundreds, and the horses strewed the line of march.

1814.—The Thames frozen. Booths were erected on the ice; oxen roasted; and a kind of fair was held, and attended by thousands. A lively description of the scene will be found in William Hone's "Every-day Book."

1849.—The frost in Norway was of such intensity that quicksilver froze.

1860-61.—Very rigorous frost in England. Fires were kindled on the Serpentine, in Hyde Park; and pyrotechnical displays took place.

1874.—A very severe frost in Scotland. Railway-trains were "snowed up," and the thermometer in some places sank several degrees below zero. A thaw began on January 1, 1875.

In Norway, where, during a great part of the year, the soil is covered with a stratum of frozen snow, the government has thought it politic to accustom a particular regiment to the use of skates; and hence it is known as *le Régiment des Patineurs*, or the Skaters' Regiment.

The soldiers of this regiment cross the lakes and frozen rivers with surprising agility, and perform a thousand difficult evolutions upon their surface. Armed with a light gun slung to the shoulder by a belt, and with a sword-dagger, they also carry an iron-shod pole, like the alpenstock which is in so much favour with Alpine explorers. With the assistance of this pole they set themselves in motion, accelerate or slacken their course, and

preserve their balance; when they wish to halt, they thrust it deep into the snow; and when firing, employ it as a support for their musket.

In the north, all the ways of communication, except, perhaps, the main roads, would be frequently closed, if the inhabitants did not resort to their skates. But the art of skating is something better to them, after all, than a *necessity;* it is a pastime, and a gymnastic exercise—in vogue, we may add, in all parts of Europe where the frost is sufficiently severe to render the frozen surface solid.

Skating, as an exercise, is very common in the towns of Northern Germany, and has drawn forth a warm eulogium from one of the most illustrious of German writers:—

"Certainly," says Goethe, "it is with reason that Klopstock has recommended this employment of our energies, which brings us into sympathy with the happy activity of childhood, excites the young to display their suppleness and agility, and assists in recalling mature manhood from its predisposition to lethargy. We [the future poet and his companions] gave ourselves up to the pastime with enthusiasm. A whole day upon the ice was not sufficient to satisfy us; we prolonged our enjoyment far into the night, by the beams of the silver moon. For if other efforts, when too long continued, fatigue the body, this, on the contrary, seems to give it more alacrity and strength.

"As young men, when their intellectual efforts have already made great progress, will throw aside everything for the simplest games of childhood, as soon as they have

once recovered the taste, so did we seem in our amusements to lose sight entirely of the more serious matters which demanded our attention. Nevertheless, it was this exercise, this abandonment to movements without object, which awakened in me noble desires too long asleep; and to these hours, which seemed utterly wasted, I owe the more rapid development of my poetical projects."

Skating has its votaries in every British town and village. For some winters they enjoyed few opportunities of gaining skill and confidence by practice; but the "seasonable weather" on which picturesque writers are so fond of dwelling returned at the close of 1874, and frozen streams, lakes, and rivers afforded them unlimited scope for the cultivation of the "art."

FLOODS.

When, as the result of a sudden change of the atmospheric temperature, the thaw produces the speedy breaking up of the ice with which winter has shackled the free energies of streams, and lakes, and rivers, the fragments tossed to and fro in the whirl of the current gradually accumulate, until they form gigantic masses, frequently the cause of terrible disasters.

And thus, as the old annalists tell us, after the very severe winter of 1408, the thaw, which commenced on the 27th of January, eventuated in frightful ravages through the overflow of the rivers. At Paris, when the ice broke up, a bank of ice, three hundred feet in length, was seen to put itself in motion and float slowly down the Seine. The houses which, in those days, covered the Parisian bridges, were severely shaken. The wooden bridge near

the Châtelet, and the bridge of St. Michel, then called the Pont Neuf, were overthrown. Fortunately no lives were lost, because the fall of the bridges and the ruin of the houses, which had been apprehended, took place in the day-time.

Some of our readers may perhaps remember the devastation produced by the great floods of 1831. On the Rhine, the Loire, the Seine, and most of their affluents, numerous bridges were entirely destroyed; and through many others, which threatened ruin, the communication was long interrupted.

The naturalist Audubon describes in graphic terms an inundation of the Mississippi. He says, that when ascending this mighty river above its point of confluence with the Ohio, he found, on one occasion, the navigation interrupted by the ice. This accident deranged all his plans, since all he could do was to order his pilot, a French Canadian, to conduct him and his party to some spot suitable for winter-quarters. He chose a locality where the river describes a great curve, called *Tawapatee Bottom.* The waters were extraordinarily low, the thermometer indicated an excessive degree of frost, snow enveloped the earth, and clouds obscured the sky; and as from all appearance there was no present hope of continuing their voyage, they all set to work very tranquilly. Their large keeled boat was moored close to the bank, and the cargo having been safely deposited in the woods, they constructed round the boat a breastwork of trunks of trees to protect it from collision with the floating ice.

In less than two days they had collected their provisions, baggage, and ammunition in a heap under one of the

magnificent forest trees; above it they stretched their sails, and a regular camp soon rose in the solitude. But how gloomy and threatening everything seemed to them! If they had not had before them in perspective the pleasure which the contemplation of a still savage nature promised to the mind, they would, says Audubon, have been compelled to resign themselves to pass the time as sadly as bears during their period of hibernation.

However, it was not long before they found both occupation and resources: the wood was filled with game, which prowled in the immediate vicinity of their encampment; while on the ice, which stretched from bank to bank of the great river, large flocks of swans were assembled, and were eyed greedily by famished wolves, whom the travellers took a pleasure in seeing disappointed of their expected prize. It was a curious sight to see these white birds crouching on the ice, but watching every movement of their treacherous enemies. If one of the latter ventured to approach, even within a hundred yards, immediately the swans were erect, uttering their cry of alarm, which re-echoed like a trumpet bray, extending their broad wings, running a few paces over the ice, which resounded beneath them with a noise like the distant roll of thunder in the woods; and finally flying away with an air of triumph, leaving the wolves completely mortified, and constrained to meditate new stratagems to satisfy the pressing wants of their appetites.

For six weeks they remained in winter-quarters; the waters had gradually declined, and, lying on its side, their boat had kept perfectly dry. The blocks of ice on each side of the river had accumulated until they formed great

solid walls. Every day their pilot went forth to examine for himself the condition of affairs, and to ascertain if there were any appearance of change. One night, while they were all enjoying a sound sleep, he suddenly arose, shouting with all his might : "The flood ! the flood ! To the boats ! Boys, take your oars, and quickly, or all is lost !" Waking with a start, and rushing forth as if attacked by a band of savages, they ran pell-mell to the bank. And, in truth, the ice was breaking up with a crash like the detonations of heavy artillery ; and as the waters were suddenly swollen, owing to the overflow of the Ohio, the two rivers dashed against one another in the utmost fury. Frozen masses, splitting up into large fragments, rose nearly upright for a moment, to fall back with a frightful noise, and plunge into the midst of the foaming waves.

Their astonishment was great to find that the weather —which the evening before had been calm and frosty—had changed to wind and rain. The water oozed through all the fissures of the ice ; the spectacle was enough to damp any one's courage. When the day dawned, it seemed still more formidable and strange. The whole mass of waters was violently agitated ; the ice which but recently covered them floated in small pieces on the surface, and though the space between each scarcely exceeded a foot, the most adventurous man would not have dared to make a step beyond. The boat was in imminent danger. The trees which had been placed around it as a protection had been severed in pieces or crushed, and their fragments beat against the frail skiff, which it was impossible to move. The pilot then employed his companions to collect great

bundles of reeds, and let them drop against its sides. And, very fortunately, before these were destroyed by the shock the boat was found afloat, and, supported on these novel buoys, was able to be moved. After this the travellers felt more at ease, and were at liberty to survey the majestic scene, when a horrible crash was heard, apparently about a mile lower down, and suddenly the immense embankment which the ice had formed gave way: the current of the Mississippi made itself a passage by driving back the Ohio, and in less than four hours the inundation was complete.

INUNDATIONS—POWER OF TRANSPORT OF FLOATING ICE—ICE-BANKS.

In the northern hemisphere, and on rivers flowing from south to north, the break-up of the ice necessarily takes place at first in the upper portion of their course. It then happens very frequently that the great fragments of the ice carried down by the waters reach those parts of the current which are still frozen, and considerable inundations are occasioned by the obstacle they form at the point of encounter. Sir Charles Lyell speaks of a partial blockade of this kind, which occurred in the Vistula on the 31st of January 1840. Arrested by the blocks of ice piled one upon another, a mile and a half above the town of Dantzig, the river was forced to take a new course on its right bank, and in a few days hollowed through sandy hills, some forty to sixty feet high, a broad deep channel, several miles in length.

In Canada, where various tributaries of the St. Lawrence begin to break up under the same conditions, great

masses of ice are seen to collect on the surface of that which is unbroken, and to form huge piles of fragments frozen together, which are soon set in motion by the force of the waters. These huge piles carry away the bridges, destroy the quays, and loosen and sweep around the rocks situated on either bank. In some parts of the St. Lawrence, these erratic blocks accumulate after every winter, and form a curious and striking scene. Some of them have been computed to weigh not less than seventy tons.

The effects of the frost are not less remarkable in the estuary of the St. Lawrence, below Quebec.

At this point, where the temperature is sometimes as low as —29°, thick plates of ice are formed at low water. When the tide rises, these are lifted up, and thrown on the sandbanks and shallows which line the estuary. When it retires, the congelation gives rise to an agglomeration of the detached fragments of rock or ice, in contact with the plates, and these masses are then carried towards the sea by a high tide, or by the waters of the rivers swollen in spring by the melting of the snow.

In the Polar Regions, where the glaciers descend to the sea, enormous fragments covered with rocky débris are frequently detached from them, and these floating masses become icebergs. The process of formation is thus described by Martins :—

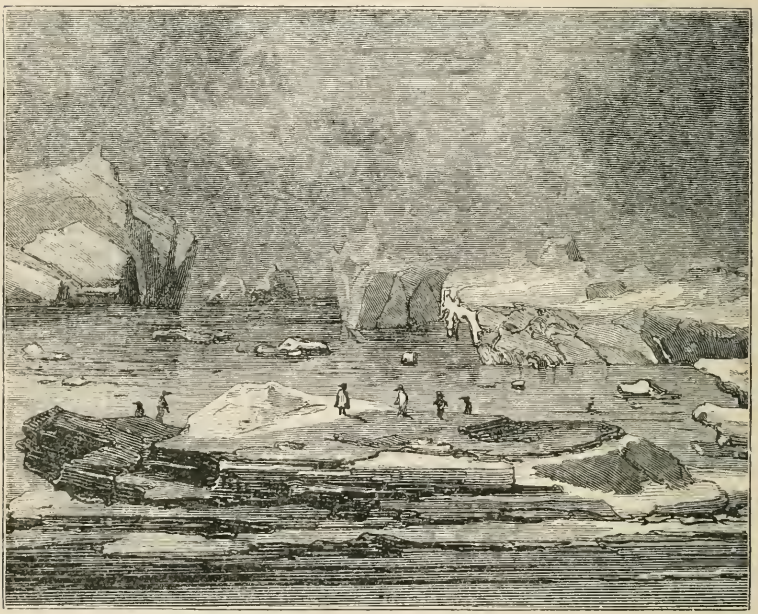
"At Spitzbergen the glacier, after a more or less considerable traject, reaches the sea. If the coast be rectilineal, the glacier does not overpass it; but in the recess of a bay, where the shore is curved, it continues to move

ERRATIC BLOCKS ON THE RIVER ST. LAWRENCE.

forward, resting upon the sides of the bay, and advancing above the water which it overhangs. This fact is easily understood. In summer, and in the depths of the bays, the sea-water always enjoys a temperature slightly above zero, and at low tide you can discover an interval between the ice and the surface of the water. The glacier, being left without a support, partially crumbles; immense blocks are detached, fall into the sea, disappear beneath the wave, to reappear after a rotation on their own axis, and oscillate for a few moments until they have gained their equilibrium. The blocks thus detached from the glaciers are what we call icebergs. Twice a day, at low water, in the curve of Bell Sound and Magdalena Bay, we were witnesses of this partial dilapidation of the extremity of the glaciers. A noise like that of thunder accompanied their fall; the swollen sea rushed in upon the shore like a sudden tide; the gulf was covered with floating masses which, under the influence of the ebb-tide, sailed, like fleets, out of the bay into the open sea, or were wrecked here and there upon the shore, at points where the water was shallow. These icebergs were not more than fourteen to sixteen feet above the water; for four-fifths of an iceberg are always submerged. The icebergs in Baffin Bay are much loftier—sometimes they overtop a ship's masts; but in that bay the temperature of the sea is below zero, the glacier does not melt on coming in contact with the water, it descends into the ocean-depths, and the portions detached from it are much loftier than all the submerged part which, in the bays of Spitzbergen, is destroyed by fusion." *

* Martins, "Du Spitzberg au Sahara."

To give the reader an idea of the grandeur of the phenomenon whose origin we have indicated, we may state that, in lat. 69° and 70° N., Scoresby counted five hundred of these floating mountains, which rose fully 100 and 200 feet above the surface of the sea, and whose circumference varied from a few yards to a mile. Many of them were loaded with layers of soil, and with fragments of rock of



BANKS OF ICE.

such a size that their weight was computed at from 50,000 to 100,000 tons.

These banks of ice approach the Equator much nearer in the southern than in the northern hemisphere. In the latter, their limit never overpasses the 40th parallel of latitude. They are sometimes met with near the extremity

GLACIER IN SPITZBERGEN.

of the great bank of Newfoundland and towards the Azores. In the southern hemisphere they advance as far as the 36th parallel, or into the latitude of the Cape of Good Hope. An iceberg discovered in this region was two miles in circumference and 150 feet in height. Other banks or bergs, rising 230 to 290 feet above the sea-level, indicated also an enormous mass, each cubic yard of ice *above* the level of the ocean corresponding to eight cubic yards *below* it.

Sir Charles Lyell very justly observes, that if the icebergs descending from the north Polar Regions advanced into equally low latitudes, the climate of a portion of southern Europe would undergo some startling modifications, and clouds and fogs would soon replace the bright and beautiful sky of those favoured regions. We may add that the cold and rainy summers of 1816 and 1866 have been attributed by meteorologists to a great break-up of the Polar ice, and to the consequent descent of the icebergs in unusual numbers to a lower latitude in the North Atlantic Ocean.

THE GLACIERS OF TIERRA DEL FUEGO.

According to Leopold von Buch, the southernmost point to which, in Europe, the glaciers descend seaward, is, in Norway, under the 67th parallel.

In South America, Dr. Charles Darwin has ascertained that the same point is found twenty degrees nearer the Equator.

This difference is due, in the first place, to the insular position of South America,—a condition very favourable, as we have already said, to the formation of aqueous

vapour and snow; next, to the presence of the cold current known as Humboldt's Current, which skirts the shores of Tierra del Fuego, and ascends as high as 38° S. lat., refreshing the climates of Peru and Chili. The considerable extent of the glaciers along the great mountain-range from the Cordilleras to Cape Horn has long engaged the attention of the navigator. But before pointing out the relations of this remarkable phenomenon to the transport of icebergs, we shall place before the reader a picturesque description of the glaciers of Tierra del Fuego :—

"When we traverse the straits which bound Tierra del Fuego on the south, we are struck with admiration at the presence of these mountains,—Mount Darwin and Mount Sarmiento,—their loftiest summits attaining the enormous elevation of 9000 and 10,000 feet above the level of the sea. The mean elevation of the chain, which stretches from north-west to south-east, is from 3300 to 4000 feet. The upper portion of these mountains is covered with snow, and their lower portion is hidden in dense forests, through which a number of foaming cascades pour the waters which proceed from the melting of the snow. In the parts which correspond to valleys, immense glaciers descend to the sea, and deposit in it enormous masses of ice and blocks of granite, or other crystallized rocks, detached from the summits of the chain. These magnificent glaciers, which are distinguished by their blue colour from the perpetual snows indicated by a dead white tint, descend from the valleys on the loftier cirques down to the very sea, into whose waves they plunge. Here and there torrents of frozen water glitter

in the midst of the gloomy forests which clothe the lower declivities of the mountains." *

These forests are truly beautiful, and, like all those of the Magellanic lands, are remarkable for the wealth and force of vegetation which characterizes insular climates. In the peninsula of Brunswick, fuchsias and arborescent veronicas flourish within a short distance of the glaciers. The western parts of the island of Chiloë, between lat. 38° and 35°, are covered with magnificent forests, which rival in luxuriance the intertropical forests; their trees attaining to extraordinary dimensions. The presence of this flora of the more temperate latitudes and of a corresponding fauna indicates the existence of climatic conditions which, joined to the disposition of the lands, explain the exceptional extension of the glaciers of South America. All the navigators who have explored these regions speak of incessant fogs, of hurricanes accompanied by showers of rain and snow, brought thither by the winds of the south. The comparison of the glaciers in different climates has shown, moreover, that the limit of the perpetual snows presents the greatest elevation in continental climates, and the lowest in peninsular and insular climates.

The support which these observations give to Professor Tyndall's hypotheses is evident, and we regret that we can do no more than indicate the remarkable approximation between his theory and the study of actual phenomena. We shall have occasion, however, to furnish some

* "Voyage au Pôle Sud," exécuté sous le commandement de M. Dumont d'Urville; publié sous la direction de M. Jacquinot.—"Géographie Physique," by M. J. Grange.

interesting details upon this same subject, when we compare the erratic soil of South America with that of Northern Europe.

ERRATIC DEPOSITS.

The immense glaciers which, from the 46th parallel of north latitude to Cape Horn, descend towards the ocean through the great valleys of the Cordilleras, frequently present, as in the Polar seas, a perpendicular wall above the level of the sea. These glaciers hurl into it considerable masses of ice, which transport to a distance the blocks proceeding from their moraines. In Eyre's Sound, where the glaciers attain an enormous development, as many as fifty have been seen floating at a time, and one of them rose to a height of 165 feet above the waters. Many of these glaciers were loaded with great boulders, and with detritus carried away from the valley-slopes. We have spoken of the prodigious quantity of débris transported by the glaciers of Switzerland. It is easy to imagine what this transport must become in the case of glaciers, of not inferior capacity, which extend over a chain of mountains 250 leagues in length. The majority of these descending to the sea-level, the débris is principally carried off by the floating ice. Thus, for example, in the island of Chiloë, which faces the Cordilleras as the Jura faces the Alps, a great number of enormous fragments of granite are found, which have probably crossed the sea on masses of ice detached from the glaciers of the coast.

To give an idea of the distance covered by this peculiar mode of transport, we shall cite the following fact, related by Sir Charles Lyell :—

In a voyage of discovery, made in 1839 to the Antarctic Regions, there was sighted, in lat. 61° S., an angular mass of very dark-coloured rock, embedded in a field of ice floating in the open sea. The visible portion of this rock was about 10 feet high by 3 feet broad; but the brownish tint of the surrounding ice showed that a great part of the stone was hidden beneath the water. This field of ice, with several others seen on the same day, was 250 to 300 feet high, and not less than 500 leagues from any known land. It is very probable that no land could be found within a hundred miles of the point where this ice-field was sighted; and the erratic block being still encased in the ice in a very solid manner, we may infer that it would traverse several leagues further before falling to the bottom of the sea.

The considerable masses of blocks and débris which are found on the western shore of South America do not proceed only from existing glaciers. Like the Swiss valleys, the valleys of the Cordilleras have preserved traces of the ancient extension of the glaciers, which formerly, there can be no doubt, covered the whole coast. It is to these primitive glaciers we must specially attribute the origin of the erratic deposit formed under the waters at an epoch anterior to the elevation of the southern part of the American continent. The chain of the Cordilleras, isolated in the ocean, then formed a series of elevated summits, the declivities of which were washed by the sea, and was thus situated under conditions peculiarly favourable to the development of glaciers. Enormous masses of gravel, rolled and striated pebbles, and erratic

blocks, were accordingly transported towards the Equator by the floating ice; and this considerable deposit, which we discover now-a-days upon the emerged superficial soil, indicates by its progressive diminution and its relation to its point of origin, the slow upheaval of the soil, in consequence of which the glaciers lost their importance, and carried down to the sea a lesser quantity of débris.

The erratic formation of the north of Europe presents a great resemblance to that of Southern Europe. At the epoch when Ocean washed the declivities of the Scandinavian Alps, the summits of which formed an archipelago, favourable hygrometrical conditions also induced in this region the accumulation of frozen snow, the extension of glaciers, the transport of boulders by the floating ice, and the deposit of erratic soil under the waters. The vast sea which received this deposit extended eastward to the foot of the Ural, south-eastward to the table-lands of Moscow, southward to the mountains of the Hartz, and covering in this way Russia, Poland, Prussia, Denmark, and the Low Countries, also included a part of Germany.

The shore of this sea is indicated by the southern limit of erratic blocks which form an immense semi-circumference with Stockholm for its centre, and for its radius the distance between Stockholm and Moscow. The blocks in this deposit, brought from the north by icebergs and ice-fields, are arranged in concentric zones.

Geological writers upon this important phenomenon attribute it to various causes which we shall shortly examine. It suffices us for the present to have indicated the contemporaneousness of the erratic formation with

the glacial period, and the similarity of the phenomena produced to those which are still observable in all parts of the globe where great glaciers descend from the mountains.

FORMATION AND APPEARANCE OF ICEBERGS AND FLOATING ICE—ICE-FIELDS AND BANKS.

The term "floating ice" generally signifies, in the Polar seas, movable masses of ice of the size of a ship. "Icebergs" are isolated masses of great dimensions. The word "ice-field" is employed by our English voyagers to designate unbroken plains of ice of from three to seven feet in height. They have been seen of 100 miles in length, with a breadth of upwards of 40 miles. Our words "ice-field," "ice-floe," and "bank," are identical in application with the French *banquise.* But the mean elevation of these impenetrable barriers is more considerable, and they sometimes attain, especially in the vicinity of the land, a height of 100 to 150 feet. Lastly, our word "hummock" refers to irregular protuberances of ice, which attract the attention by their fantastic forms, and frequently rise to very great elevations.

By its mere appearance, you can easily distinguish sea-water ice from fresh-water ice. The former is porous, opaque, white, and light is transmitted through it with bluish or greenish tints. The ice of littoral glaciers exhibits a beautiful green colour, and is often as pure as crystal. The density of floating ice is variable, according to its locality and its mode of formation. Hence it results that its ratio of flotation varies between 1.9 for the maximum of density, and 1.7 for the minimum. In the former case, a block of ice of 30 feet thick would rise

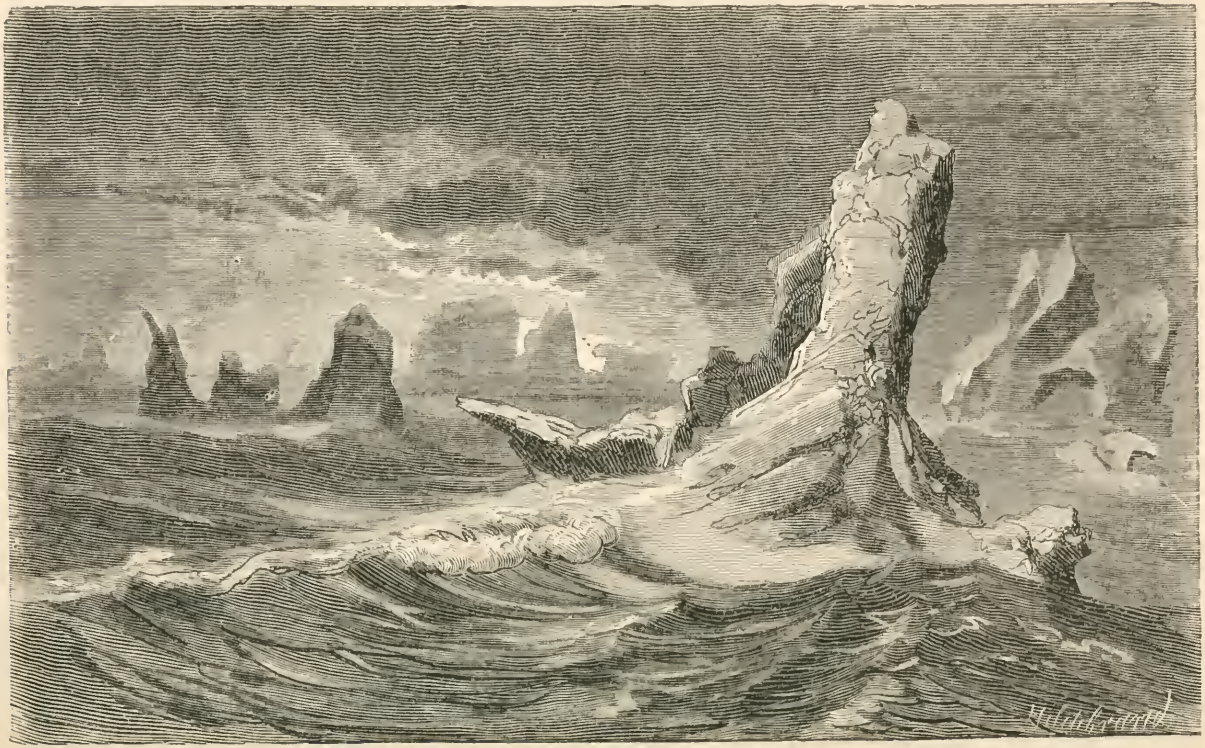
only three feet above the level of the sea; in the latter it would rise about four feet.

Plateaus of ice, or ice-fields, will sometimes form on the surface of the sea, at a great distance from the land. Several navigators have seen this operation take place under their own eyes; and Scoresby has described its different phases:—"I have frequently observed," he says,* "the process of congelation, from the first appearance of the crystals until the ice had attained a thickness of upwards of an inch, without the land in any way assisting in its formation; and frequently in places where the old ice having been driven by the currents or the east winds, the lands situated to the west had prevented new ice from taking its place.

"I have seen ice forming at upwards of twenty leagues from Spitzbergen, and rapidly acquiring a consistency capable of arresting the movements of a ship propelled by a good breeze, even when it was exposed to the waves of the Atlantic Ocean, in the midst of the Greenland Sea, under the 72nd parallel of latitude.

"When the first elements of ice appear on the surface of the sea, under the form of minute isolated crystals, resembling snow which the cold water cannot melt, the sailors call it *sludge;* the tumult of the billows subsides as if they had been covered with a coat of oil. The crystals unite together to form larger kernels; and even under the influence of the waves they acquire dimensions of three to four inches in diameter. These little icicles, constantly dashing one against another, become rounded,

* Dr. Scoresby, "An Account of the Arctic Regions."



FLOATING ICE.

again unite, and soon present the appearance of small plates, a foot in thickness, and several yards in circumference. They are then named *pancakes;* and if you were to examine them, you would see that they have the form of paving-stones.

"When the sea is not agitated, the process of congelation is very rapid. The ice increases from its lower part, frequently attains a thickness of two to three inches in twenty-four hours, and is able to sustain the weight of a man in less than forty-eight hours. These newly-formed plateaus are named by the English sailors *young ice*, or *bay ice*."

Numerous strata of snow are soon deposited upon the surface; they continue to augment; and eventually they form the immense plains of ice which the whalers encounter in spring in the seas of the North.

This floating ice does not acquire a great thickness unless it remains accidentally attached to the coast, in a latitude where the moistness of the climate is favourable to the fall of a great quantity of snow, which condenses on its surface, and in spring is reduced to *névé*. It is thus that during a long series of winters enormous and regularly stratified masses are created, which preserve their character of horizontality, and whose forms in general approximate to that of a parallelipiped. These masses, which are frequently from 150 to 180 feet in height, and two to three miles in length, appear in all cases to be the remains of an immense plateau, divided into portions of equal height. The magnificent ice-fields which cover the seas of Greenland, and the ice-banks of the southern continent, have undoubtedly this origin, which alone permits

of an explanation of their uniform elevation and horizontal character.

The masses detached from the glaciers, the lower portion of which plunges into the sea, are infinitely less considerable, and affect the most irregular forms. Excavations, vaults, and arches are hollowed by the action of the waves in the face of these glaciers; and the same effect is produced on the floating masses. When the temperature of the sea rises, the base begins to melt; and soon, under the shock of contending billows, the mass crumbles and tumbles over, raising towards the sky a variety of needles, columns, pilasters, and turrets, which form the only remains of the lower portion.

The form and dimension of icebergs are infinitely variable. Their relative arrangement in lines or groups is determined by the winds, by the currents, and by all the accidents of a stormy sky. Sometimes they resemble immense fields of 3 to 15 feet in height,—these are perfectly level plains, covered with snow; sometimes a front of enormous blocks, from 30 to 150 feet, forming a continuous coast, an impenetrable ice-field, with all the indentations and irregularities of the cliffs of a mountainous shore. Further out at sea, these *banquises*, these fields of ice, separate into groups; still further, they are reduced to islands and scattered islets.

These immense ruins of an inert world assume all the modifications, all the forms, all the figures which Ocean imprints upon them: vast plains, united under a peaceful sky, are scattered into ruins by the tempest, which, in headlong fury, dashes one against another, and raises

AN ICE-FIELD.

their relics into singular monuments and fantastic mountains, frequently 320 feet in height.

When the ice has been a long time afloat, it frequently presents the form of a mushroom. It has been deeply wrought away to the level of the line of flotation, and from the summit hang a myriad huge stalactites of many colours.

This ice is generally very hard; yet, under the influence of circumstances at present not well understood, it grows softer, and the least shock is then sufficient to reduce it to powder. Such phenomena are most numerous under the action of hot and damp winds.

Ice detached from the walls of ice, the *banquises*, which terminate the glaciers, is usually denser than that formed on the surface of the sea. Its outlines are generally irregular. They frequently present fantastic figures, such as Gothic edifices, pyramids, and marble palaces; but more frequently their forms are so strange that we can compare them to nothing on land or sea. Their stratification, less perceptible and far less distinct than that of other floating ice, is perfectly regular; their azure colour is generally more vivid, and the water which they yield in melting is fresh enough for the use of crews.

These glacier fragments are generally isolated, or in scanty groups, and very rarely in uniform masses, like the remains of an ice-field. They alone exhibit the semblance of those magnificent monuments which by their elevation and design impress the traveller with astonishment and admiration.*

Navigators accustomed to the Polar seas recognize at

* "Voyage au Pôle Sud." "Géographie Physique," par M. J. Grange.

great distances, by the colouring of the clouds, and by the peculiar splendour with which the horizon glows, the presence of floating ice. Thus, the nautical word "ice-blink" describes a *whiteness* which appears in the part of the atmosphere situated above a great extent of ice. The

AN ICEBERG IN THE SOUTHERN OCEAN.

yellowish tint of the sky indicates a land covered with snow, and is distinguished by the name of the *land-blink.* Near the ice-fields, the clouds are generally of a dazzling whiteness, produced by the reflection of the solar rays. Rear-Admiral Beechey speaks of the strange aspect which

this refraction of the ice gives to the sky, where, in the calm of a silvery atmosphere, a supernatural brightness seems to glow. When the sea is open beyond the ice-field, a kind of blackness gathers on the horizon, and our sailors name this gloomy aspect of the Polar sky above the northern waves a *water-sky*.

III.

Ice in the Polar Regions.

"Here let the billows stiffen, and have rest."
S. T. Coleridge.

THE SOUTHERN ICE-FIELD.

NO navigator before Cook ever undertook to penetrate into the Antarctic Regions. Our government had entrusted him with the mission of circumnavigating the globe, while keeping as far as he could within sight of the ice; and he carried out this exploration in 1773 and 1774 with a constancy and intrepidity rarely equalled. The windings of a continuous ice-field permitted him to approach only the parallel of 71° 15′; at one point alone he perceived beyond this barrier a succession of white mountains which had their summits in the clouds; but the icebergs, by their number and distribution, revealed the existence, and, in a certain measure, the form, of a continent situated in the direction of the Pole. At the same time, he was of opinion it would never be possible to approach it.

The dangers, he says in his narrative, which one would incur by seeking to explore these terrible seas, are such

that no person, I think, will ever venture much further, and the lands lying south of the 71st parallel will remain eternally virgin.

This assertion of the gallant captain for a long time paralyzed the ardour of the mariners of all nations, and it was not until the beginning of the present century that any new attempts were made. Russia despatched a vessel commanded by Bellinghausen, who did not attain a higher latitude than Cook. It was Weddell, a seal-hunter, who, in February 1823, found the sea open as far as 74° 15′, and communicated by this discovery a lively impulse to enterprising spirits. The principal instruction received at a later date by Dumont d'Urville was, to assure himself up to what point it was possible to follow the route indicated by Weddell towards the Southern Pole.

The expedition placed under his command consisted of two corvettes, the *Astrolabe* and the *Zélée*, equipped at Toulon in the spring of 1837. He did not succeed in finding the hoped-for channel, but he made some interesting observations, though his discoveries had not the importance which some French geographers would fain attribute to them.

His ships, on quitting the Orkney Islands, had not advanced as far south as 65° before their route was interrupted,—the look-out man announcing that the passage was blocked up. An immense field of compact masses of ice, piled one upon another, extended as far as the eye could see from south-west to north-north-east. They had arrived within two miles of this impassable barrier.

Under these circumstances, the commandant, Dumont

d'Urville, decided on following the coast-line of the ice, by steering in an easterly direction. "The breeze fell," he says, "and we scarcely accomplished a knot in four or five hours. We had, therefore, an opportunity of contemplating at our ease the marvellous spectacle before us. Sublime and majestic beyond all expression, while elevating the imagination, it filled the heart with a sentiment of involuntary dread; nowhere does man more keenly feel the sentiment of his own powerlessness. It is a new world whose image is revealed to his gaze, but a world inert, gloomy, still, where everything seems to threaten the annihilation of his faculties. There, if he had the misfortune to remain abandoned to himself, without resource, without consolation, not a spark of hope would brighten his last moments !.....

"Though it is impossible to furnish a satisfactory description of this singular scene, so that it shall be realized by those who have not seen it, we may attempt to particularize a few special features.

"To the very confines of the horizon, to the east as to the west, extends an immense plain of blocks of ice, of all forms, heaped up, and confusedly intertangled one with another, almost exactly as you may see them on the surface of a great river when a thaw occurs. Their mean elevation does not exceed 13 to 16 feet; but on this frozen plain rise here and there blocks of far greater size, and fully 100 to 130 feet high. These seem to be the colossal edifices of a city of white marble or alabaster.

"The edges of the ice-field are generally well defined, and hewn precipitously like a wall; sometimes they are

ENTERING THE ICE-FIELD.

rent, and broken up into small shallow creeks or canals which boats can navigate, but are scarcely large enough to receive our frigates. Accordingly, the neighbouring blocks of ice, agitated by the waves, are in a state of continual movement, which cannot fail in due time to cause their destruction.

"The habitual tint of these ice-blocks is grayish. But when the rays of the sun illuminate the scene, the optical effects are truly marvellous. It seems as if a vast city revealed itself in the midst of the frost, with its houses, its palaces, its fortifications, and its belfries. Sometimes you would think that a village was before your eyes, its houses and trees powdered with flakes of snow.

"The most profound silence prevails in the midst of these icy plains, and life is represented only by a few petrels, noiselessly flying,—or by some whales, whose hoarse lugubrious moan at intervals relieved the desolate monotony. In the immediate vicinity of the ice-field, the floating fragments of ice are numerous, but they are neither united together nor agglomerated, as one would expect in the neighbourhood of compact ice."*

A SOJOURN ON AN ICE-FIELD.

Sailing along the margin of the ice-field presented great dangers, on account of the numerous floating masses of ice which our voyagers encountered, and which could only be avoided by skilful manœuvring. These dangers were frequently increased by thick-gathering fogs and heavy showers of snow.

* "Voyages des corvettes *l'Astrolabe* et *la Zélée* au Pôle Sud et dans l'Océanie," par Dumont d'Urville.

Each time that they approached the massive barrier, they were greeted with almost exactly the same spectacle,—a vast extent of ice of fantastic forms and varied colours. Sometimes they seemed of a blackish-gray; at other times, a green hue, more or less intense, predominated; but more generally they were of a dazzling blue or white. At certain points, along the edge of the ice-field, they were disjointed and changed by the thaw; it was supposed that here a passage might be found, but each attempt was speedily arrested by an impassable barrier. In one of these adventures, Dumont d'Urville was for several days blocked up in the midst of the ice. Profiting by a favourable wind, he had launched his ships into what seemed an open channel, avoiding only the collision of the larger fragments, and crushing the others with the vessel's stern. This audacious manœuvre was for some time successful; the stout corvettes triumphed over all obstacles; they experienced such violent shocks that the keels vibrated in every part. The saw adjusted to the knee-post of the *Astrolabe* acted at first with considerable success; but repeated collisions shook the nails which held it, and at length one stronger than all the others completely detached it. The snow, moreover, became so intense and so continual, that the commodore was compelled to order his ships to lay-to. The sails were furled, and a novel kind of moorings laid down, by fastening the cables to great masses of ice, which thus served as floating anchors.

On the following days attempts were made in different directions; under a press of sail the ice was tried, and when a passage could not thus be forced, the ships were

IN THE MIDDLE OF AN ICE-FIELD.

hauled along, painfully and slowly. Ropes fixed to the most solid projections were coiled around the capstans, while the seamen endeavoured to facilitate the ship's advance by keeping the floating ice from off her sides.

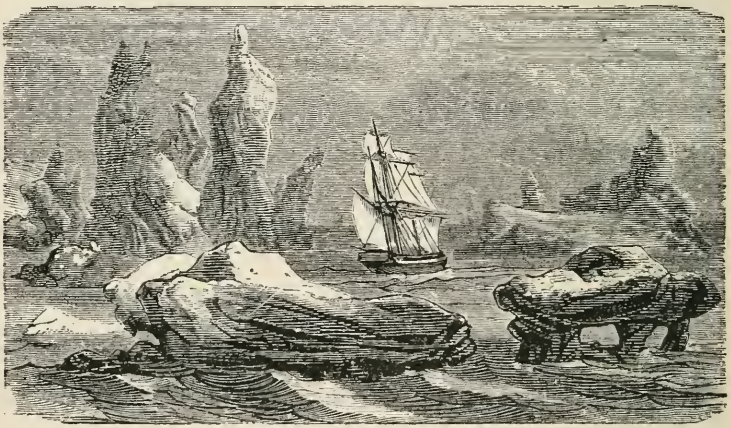
In these difficult circumstances Dumont d'Urville held a consultation with the captain of the *Zélée*. It proved to him, at all events, that his comrade's zeal and constancy were not shaken by the perils they had already incurred, and by those which still threatened them. "Not a complaint, not a regret escaped him, and expressing his readiness to follow me wherever I was willing to lead, he displayed the same satisfaction, the same devotion, as of old. Such noble sentiments did not a little contribute to maintain my own courage; assured of the agreement and sympathy of so worthy a comrade, I felt myself capable of the greatest efforts worthily to accomplish my task."

New attempts were undertaken, but they led only to a very slight advance, and the ice became so closely packed, owing to the fresh winds which had begun to blow from the northward, that it became impossible to make any movement whatever. Yet the open sea was not very far off, for they heard the roar of the waves breaking on the margin of the ice-field, and the swell was violent enough to make the entire frozen plain oscillate as if tossed by an earthquake.

Fortunately, the wind changed on the following day to the south-east. The ships set sail, and proceeded for some time with very great rapidity; but, after awhile, they were again arrested in their course by compact masses of ice; these were cleared by means of the cables;

then they again resumed their voyage, and at length the open sea became visible at a short distance.

Just as we had hauled in our last cables, says Dumont d'Urville, a sad accident nearly happened. I had given the order, All hands on board. Everybody had promptly regained the vessel; except the calker, a man of great zeal and activity, who had volunteered to assist the seamen in their labours. He was left behind, being frequently delayed in his return by the numerous fissures in the ice.



ESCAPING FROM THE ICE-FIELD.

He ran and leaped with all possible speed; but when the fissures were very wide, he was compelled to make considerable detours, and meanwhile, in spite of all my efforts, the corvette forged ahead. For a moment I feared lest I should be forced to leave this poor wretch among the ice, for had the corvette once emerged, I could not have ventured upon re-entering, nor even upon launching a boat to save him. At length, to my great joy, he reached the ship, and we hauled him aboard more dead than alive.

ADELIA AND VICTORIA LANDS.

In the month of January 1840, D'Urville resolved on a new expedition towards the South Pole, starting on this occasion from Hobart Town, Tasmania. The region which he explored was exactly opposed to that in which he had made his first attack upon the ice-field. After he had got clear of the ice, a new land, forming a portion probably of the Southern Continent, greeted the eager gaze of the mariners.

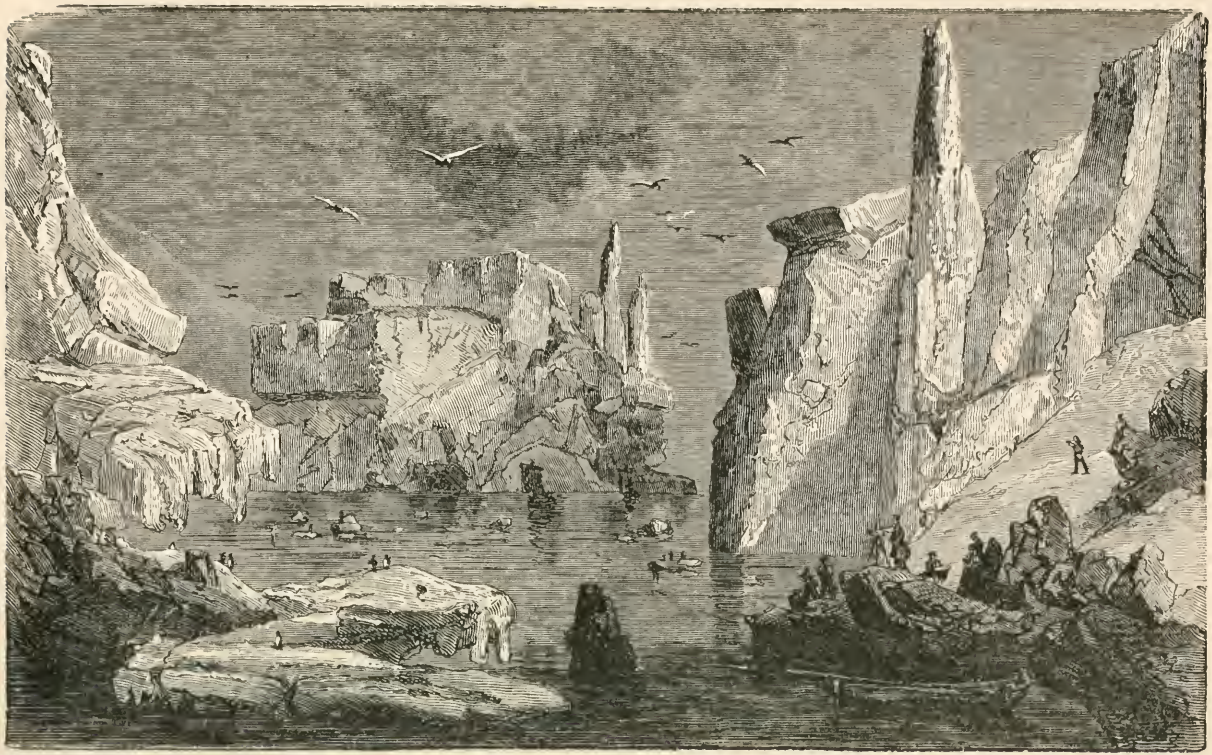
"On the 21st," says Dumont d'Urville, "I took advantage of a fair south-east wind to sail in a south-south-west direction towards the land. To reach it, we had to traverse an immense chain of icebergs in the form of tables, and of the largest dimensions. I sought with my eyes for the most open and the least perilous channel. From two to six o'clock, our corvettes threaded their way tranquilly through these novel straits. Sometimes these canals were not more than three or four cables' lengths in breadth, and then our ships seemed buried under their resplendent walls of 100 to 150 feet in vertical elevation. Then, the canal suddenly opening, we passed into wide and spacious basins, surrounded by ice of fantastic forms, recalling the palaces of crystal and diamonds in fairy tales.

"A bright sky, delicious weather, a favourable breeze, served us admirably in this navigation. At length we emerged from these narrow and winding channels, whose lofty walls had long hidden from our sight the land, and we found ourselves in a space comparatively free, where we were able to survey the whole visible extent of the coast.

"About eight or ten miles distant from us, it rose like an immense rampart, from 1200 to 1500 feet in height, entirely covered with ice and snow, which had levelled the summit, while leaving intact the ravines on the sloping lands, as well as the bays and projections of the shore. Sometimes these ices offered but a level, uniform sheet of a dead and monotonous whiteness; sometimes their surface was furrowed, jagged, and broken, as if it had undergone the most violent convulsions."

When the ships had approached near enough, some boats were sent to the shore, for the purpose of collecting granitic rocks of varied tints, and specimens of *fucus*. The new land was named by its discoverer *la Terre Adélie*, as a token of his deep attachment for the devoted companion who, by consenting to a long and painful separation, had enabled him to accomplish his exploring projects. The reader will not fail to deplore the unfortunate destiny of the admiral who, almost immediately after his return to France, perished, with his wife and their young son, in the terrible catastrophe on the Versailles Railway.

The great results achieved by the French expedition were of some advantage to Sir James Ross in leading him to the discovery which has rendered his name immortal. His principal object was to ascertain the position of the South Magnetic Pole, which Dumont d'Urville had approached very nearly in his survey of Adelia Land. He sailed southward in January 1841, on a meridian further east by several degrees; encountered the extremity of the bank a little beyond the 63rd parallel of



THE DISCOVERY OF ADELIA LAND BY DUMONT D'URVILLE.

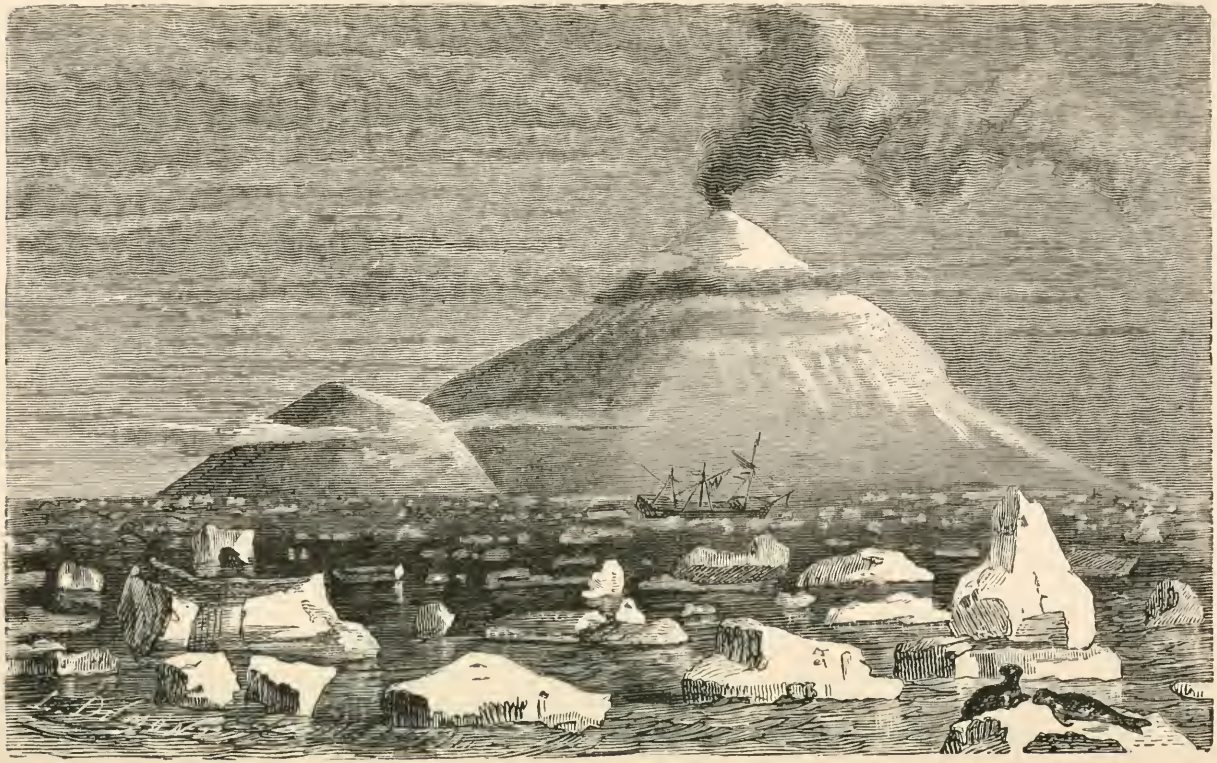
latitude; fell back at first, and was driven still further to the east by a storm, after which he recovered the barrier in 66°. The wind and the sea both carrying him towards it, he resolved on an attempt to cross it. His success was complete, in spite of the thick fogs and feeble winds which soon rendered his voyage as painful as it was perilous, and the heavy showers, or deluges, of snow which impeded the manœuvres of the vessel. Ross, however, was encouraged by the circumstance that, at each clearing up of the weather, he perceived in the south-east a "watery sky," evidently reflecting an open sea; which he reached on the 9th of January, after having penetrated the ice-field for upwards of two hundred miles.

On the 11th, in 70° 47′, land was discovered. It presented a magnificent picture of precipitous mountains, from 10,000 to 15,000 feet in height, entirely covered with snow, and with immense glaciers on their declivities, projecting like capes into the sea. Here and there the crests of some barren rocks were discernible; but the coast was so beset with ice that it was found impossible to land. Captains Ross and Crozier succeeded in effecting a descent only on two islands,—one of which was situated in 71°, and the other in 76°,—and of which they took possession in the Queen's name. They were evidently of volcanic origin, and proved to be the precursors, or advanced posts, as it were, of a region where the subterranean forces had broken out with no ordinary violence. In 77° 30′ Ross discovered a mountain, 12,000 feet high, vomiting enormous clouds of flame and smoke, with another mountain at its side, nearly as lofty, but extinct, or at least inactive. To these twin colossi of the Antarctic Continent

were given the names of the two ships of the expedition, *Erebus* and *Terror*,—harmonizing, certainly, with the desolate aspect of this strange wild region.

A few days later, in 78° S. lat., our navigators fell in with a barrier of ice which rose 160 to 170 feet above their topmasts, and beyond whose dull gray line could be perceived the summits of a lofty mountain-chain. It seemed as if they had arrived at the bottom of a great gulf hollowed out of the Arctic mainland, for after sailing about 300 miles towards the east, and coasting along the barrier, they were checked by an extremely dangerous ice-field, which compelled them to tack and bear towards the north.

After this brilliant enterprise, which had accomplished what Cook considered to be impossible, Captain Sir James Ross conducted two other expeditions; but these proved less fortunate in their results. On the 18th of December 1841, he fell in with the ice-field 300 miles more to the northward than in the preceding year. He entered it, nevertheless, and advanced up as far as the increasing thickness of the ice permitted, and up to a point where the extraordinary brilliancy of the sky towards the south indicated the presence of insuperable masses. Bearing towards the east, where appearances seemed more favourable, he had found a few miles only of open sea before a violent hurricane exposed his ships to the greatest dangers. Both of them lost their helms, and thus disabled, had to struggle a whole day against the masses of ice which pressed around them. The gale,



MOUNTS EREBUS AND TERROR IN THE ANTARCTIC CIRCLE.

however, subsided quickly; Ross repaired his steering apparatus in the very midst of the ice, and got clear of it on the 2nd of February, after an imprisonment of six-and-forty days.

In his third voyage his explorations were directed to Graham Land, south of Cape Horn. He aimed at pushing in between its coast and the ice-field, so as to reach the great open sea described by Weddell. In this he did not succeed; but he discovered a very considerable extent of new land, which appeared to him a portion of the Antarctic Continent. This land was covered with snow, and immense glaciers stretched down into the very sea, abandoning to the currents their floating icebergs.

He ascertained that most of the visible rocks were of a volcanic character; one island which he was able to approach contained a vast crater on the summit of a cone, 11,500 feet in height.

From the narratives of these various navigators we see, then, that the latitudes in which the ice-fields are chiefly met with differ greatly year by year, and even in much shorter periods. Ordinarily, when you approach these barriers, you meet at first simply with a multitude of floating fragments of ice, uniting in groups, sheets, or curved lines, according to the caprice of the winds and currents. Frequently they present a number of concentric zones, the most extreme of which are composed of half-melted blocks, and the next of blocks of greater size, sometimes as large as a small ship. You may easily cross for some two or three miles in the open channel

between each zone. Further in, you may also traverse groups of large isles of ice, by passing through the canals which separate them; and it is only after this that you dash against the impenetrable rampart. When the ice is thus disposed, it is by no means difficult to understand how, with violent winds blowing for several successive days towards the south, a space which has been navigated easily at a given epoch should rapidly become impassable. Under the impulse of these winds, the blocks put themselves in movement with different degrees of velocity, according to their size. The smaller fragments reunite with those which follow them, the concentric zones draw close together as well as the great islands, and a slight decline in temperature is then sufficient to induce a process of regelation among all these compressed portions and masses of ice, until a compact field, of far greater extent than the original, is duly formed.

GLACIERS IN THE POLAR REGIONS.

The extraordinary magnitude of the icebergs met with in the seas of the southern hemisphere was the first indication of the presence of vast glaciers in the austral lands. This prevision has been confirmed whenever our navigators have succeeded in catching sight of them. It would be far from the truth, says Grange, to represent to one's-self the Polar glaciers with the associations or recollections of Switzerland and the Pyrenees. They exhibit a spectacle of really indescribable grandeur; the astonished voyager cannot but admire the magnificence of the scene, but, at the same time, he experiences a sentiment of terror wholly irrepressible, when he sees all around him a

lifeless and silent nature. How different from the mountains of Switzerland, where the azure crests of the glaciers crown verdant meads and luxuriant forests! Here earth is inert, nature inanimate; a sky of lead, an incessant fog, and dense gloomy mists, invest the glaciers with a gray and sombre hue; absolute stillness reigns on these sorrowful shores, where the only representatives of life are a few birds of prey, a few long-winged petrels, which frequent the solitary waste,—some flocks of penguins perched on the crags and ledges of the glaciers, or sporting among the foamy waves,—or the straggling whales which seek an asylum in the ice-deserts of the Poles.

Vertical walls several leagues in extent, and from one hundred and sixty to one hundred and eighty feet in height, frequently terminate the glaciers abutting on the coast. The extremities of the Swiss glaciers are far from attaining these dimensions, as you may judge from the masses which they deposit in the mountain *cirques* and valleys.

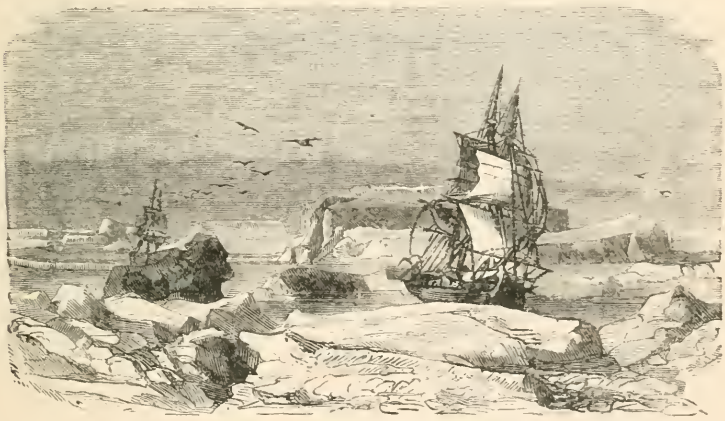
Maury, in his "Physical Geography of the Sea," seeks to explain the cause of this great extension of the austral glaciers. It is due, he says, to the hygrometrical nature of the prevalent winds, which, blowing from the north-west, sweep over a vast area of ocean before penetrating into the icy zone. Thus they load themselves with abundant vapours, and transport their burden to this region of lofty mountains, which here perform the part, and discharge the functions, of an immense condenser. The extent and massive character of the glaciers and icebergs of the South Polar Regions are, therefore, in harmony with

climatological conditions, and do not depend, as some have thought, on any special inferiority of their temperature compared with that of the North Polar. According to the illustrious meteorologist whom we have just quoted, the latent caloric disengaged by the very considerable precipitation which is always taking place there, ought even to secure for the southern regions a climate comparatively mild. This fact is dwelt upon very prominently in the various appeals addressed by Lieutenant Maury to the maritime nations, with the view of inducing them to resume their expeditions towards the Antarctic Pole, which have been suspended for upwards of a quarter of a century. He specially invites the future explorer to attempt a winter in the Southern Seas. He is of opinion that it would entail no extraordinary hardships, while it would render possible the collection of a precious harvest of scientific observations.

The glaciers of the Pole present very similar characteristics to those of less inhospitable lands; however, in some few respects they differ, and to a superficial ob server would seem independent of the laws we have expounded in the preceding pages. M. Charles Martins, who carefully studied the glaciers of Spitzbergen, during the scientific expedition of the *Recherche* to that melan cholly island, has very clearly shown that such is not the case, and that we have simply to consider a peculiar example of the general phenomena. He points out, in the first place, the rare occurrence of *needles* and prisms of ice, which must be attributed to the slight inclination and the uniformity of the slopes, as well as to the

diminution of the solar heat, which, even in the long summer days, never thaws the surface. Nor are there any streams to hollow out crevasses, and mould the rugged asperities. Nevertheless, we invariably meet with transversal crevasses produced by the movement of the glaciers, and these are frequently very broad and very deep.

In the terminal escarpment, which fuses or melts in proportion to the extent it plunges into the sea, caverns



THE "RECHERCHE" IN AN ICE-FIELD.

of immense size are sometimes discovered, with which the azure grottoes of the Arveiron and Grindelwald, so much admired by travellers, cannot for a moment be compared. "One day," says Charles Martins, "after taking the temperatures of the sea before the glacier of Bell Sound, I proposed to the sailors who accompanied me that we should take our boat into its cavern. I explained to them the nature of the risk they would run, being unwilling to take advantage of their ignor-

ance. They unanimously agreed to venture. When our boat had crossed the watery threshold, we found ourselves within an immense Gothic cathedral: long, conical-pointed cylinders of ice descended from the roof; the recesses seemed so many chapels attached to the principal aisle; broad crevices divided the walls, and open spaces, like arches, rose towards the vault; while azure lights played upon the ice, and were reflected in the water. My sailors, who were all Bretons, were, like myself, dumb with admiration. But too prolonged a survey had been dangerous; we speedily regained the narrow opening through which we had penetrated into this Temple of Winter, and, returning on board the corvette, kept silent upon our escapade, which might have been justly censured. In the evening we saw from the shore our gorgeous cathedral, which we had that morning visited, slowly sinking, then detach itself from the glacier, plunge deep into the waves, and reappear in a thousand broken fragments of ice, which the ebbing tide carried out towards the open sea."

We do not discover on the Spitzbergen glaciers that great number of moraines which is so marked a feature of the majority of those of Switzerland. The mountains, being of no considerable altitude, are, as it were, buried beneath or sunken into the glaciers, instead of dominating over them, and only their summits rise above the surrounding mass. Consequently, very little débris falls upon the latter. Martins compares the glaciers of Spitzbergen to the upper portions of those of Switzerland; that is, to the part above the line of perpetual snow.

"Now," he adds, "the higher we ascend upon an Alpine glacier, the more do the lateral and medial moraines diminish in width and solidity, until at last they disappear altogether under the elevated *névés* of the *cirques*, or basins, of which the glacier is simply an emissary; just as the mountain torrents frequently originate in one or in several lakes situated at different levels. For all these reasons, few lateral and medial moraines are found on the Spitzbergen glaciers; a certain number of blocks may be noticed on the borders, and sometimes in the centre, but the ice never disappears, as in the Alps, under a superjacent mass of ruin. As for the terminal moraines, they must be sought at the bottom of the sea, since the terminal escarpment nearly always overhangs it; thus, the blocks of stone fall simultaneously with the blocks of ice, and form a submarine frontal moraine, the two extremities of which are sometimes visible upon the shore."

THE NORTH-EAST PASSAGE.

The first navigators to penetrate into the North Polar basin were whalers pursuing their prey from one place of refuge to another, as it constantly retreated before them. As early as the sixteenth century, the Basques had ventured as far as the coasts of Iceland and Greenland. At the beginning of the seventeenth century the English and Dutch, who repaired in great numbers to the Spitzbergen fisheries, sailed beyond the eightieth parallel of north latitude. Thus hotly hunted, the whales passed under the ice-field, to regain the surface of the sea only in some free open arms scattered here and there among its frozen crust. Even there they were not safe from their enemy;

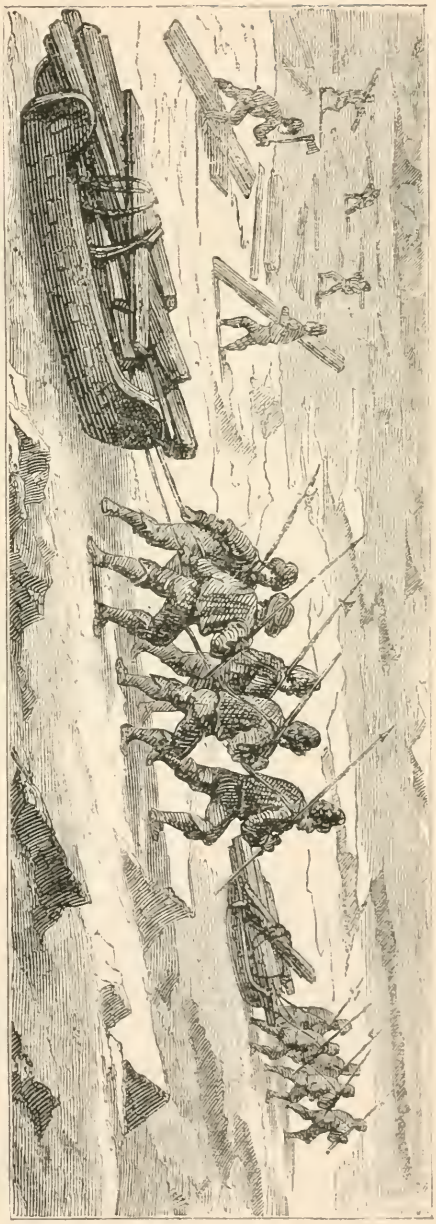
the fishermen frequently profiting by a favourable wind to cleave the ice with the iron bows of their ships, and fall upon them in their remote retreats.

Another commercial interest arose as a stimulus to prompt the navigation and exploration of these seas. This was the search after a passage to China and India by the north of Asia, so as to avoid the long and dangerous route by way of the Cape of Good Hope. This search was undertaken by the Dutch with peculiar enthusiasm after they had thrown off the yoke of Spain, towards the end of the sixteenth century. Necessarily they did not obtain a result which the experience of two hundred years has proved to be unattainable; but Science owes many important discoveries to their expeditions, especially to those commanded by Barentz, a seaman of great courage and rare ability. In his first two voyages he explored the White Sea, and the coasts and creeks of Novaia Zemlaia. Each time he got clear of the ice before winter, and returned to Holland; but his third voyage was less fortunate, though it had commenced with the discovery of Spitzbergen.

After their departure from that island a terrible gale drove our adventurous navigators on the shores of Novaia Zemlaia, where they found refuge in a little bay, which they not unfitly named the *Port-des-Glaces*, or Port of Ice; for here, towards the close of August, they were blocked up, and compelled to pass the winter. Assuredly they would have perished of cold, had they not found sufficient driftwood on the shore to furnish them with fuel and the material for building a hut. The narrative of their sufferings, written by one of themselves, bears

striking testimony to the admirable firmness with which they endured the severity of an excessive cold, and the repeated attacks of ferocious bears.

This journal also contains some remarkable observations on the opening of the ice, which in mid-winter takes place at numerous points; a phenomenon caused by the check experienced at this season by the Polar current, as well as in the movement of the Gulf Stream which follows it up, and which conveys to the shores of Novaia Zemlaia the fallen trees carried down to the sea by the rivers of America.



BARENTZ AND HIS CREW GATHERING THE MATERIALS FOR BUILDING THEIR HUT.

As early as the latter days of February the Dutch, seeing the sea open over a vast extent, indulged in hopes of a speedy departure. But returning tempests brought fresh

BARENTZ'S HUT, NOVAIA ZEMLAIA.

supplies of ice, and it became impossible to disengage their ship. In June Barentz decided on abandoning her, and in setting out with his crew in two large boats.

They had scarcely got on their way when the death of the courageous captain plunged his companions into despair. Necessity, however, compelled them to gird up their loins; and after suffering severely, and incurring many perils, they safely accomplished their difficult homeward route. There are on record numerous instances of long voyages undertaken in open boats, but not one, not even Bligh's celebrated voyage from Tahiti to Timor,* can be compared with this. Fourteen men accomplished a passage of upwards of eleven hundred miles, exposed to the danger of being engulfed by the tremendous billows of the Polar seas, or crushed by the collision of huge icebergs, enduring for forty days the severest excesses of cold, hunger, and fatigue. However, with the exception of two men who were ill when they embarked, and who died on the voyage, they arrived in safety at the Russian port of Kola, where they found a Dutch ship which carried them back to their own country.

Fresh attempts were made at the commencement of the seventeenth century to reach the Eastern Ocean through the seas of the North Pole. A company of English merchants placed an expedition for this purpose under the command of Henry Hudson, who had already acquired a great reputation as a seaman of resolution, courage, and skil. But he could not get beyond 80° N. lat.,—being arrested by a compact barrier of floating ice. Captain Poole at the head of an expedition equipped by a Russian company, could not pass the fatal eightieth parallel, the

* The mutineers of the *Bounty* flung their captain, Bligh, with a few officers and men, into a small undecked boat, in which he and his companions safely performed a voyage of upwards of 10,000 miles.

ice-wall which abuts upon Spitzbergen extending far to the westward. Two other experienced seamen, Baffin and Fotherby, were not more fortunate. When, a century later, Captain Phipps, R.N., recommenced the search after this passage with a couple of ships, carrying several scientific explorers, he ascended as far as 80° 48′, and discovered in this high latitude the island which bears his name. But this discovery proved his *ne plus ultra;* from the summit of a lofty mountain the eye ranged in an easterly and north-easterly direction over a space of thirty to forty miles of ice, which extended to the very horizon.

A JOURNEY ACROSS AN ICE-FIELD.

A passage in the narrative of Phipps, describing this vast frozen plain, suggested to Sir Edward Parry, in 1827, the bold idea of reaching the Pole by crossing the ice in boat-sledges, which could, when opportunity offered, be launched in the open sea. The expedition failed, but not until Parry had ascended as high as the eighty-third parallel of latitude; a point which has never been over-passed by any other explorer. The courage and energy of this illustrious officer and his companions have rarely been equalled, and they were displayed in the midst of the most perplexing circumstances which can be encountered in the Polar Regions.

The ship *Hecla*, on board of which he hoisted his flag, sailed from Greenwich at the end of March; it carried a couple of boats, very carefully constructed, and each capable of containing fourteen men, to be used in crossing the ice-field. A long time was lost among the ice, and the ship did not reach Spitzbergen until June 20th.

RELIEF OF BARENTZ'S CREW.

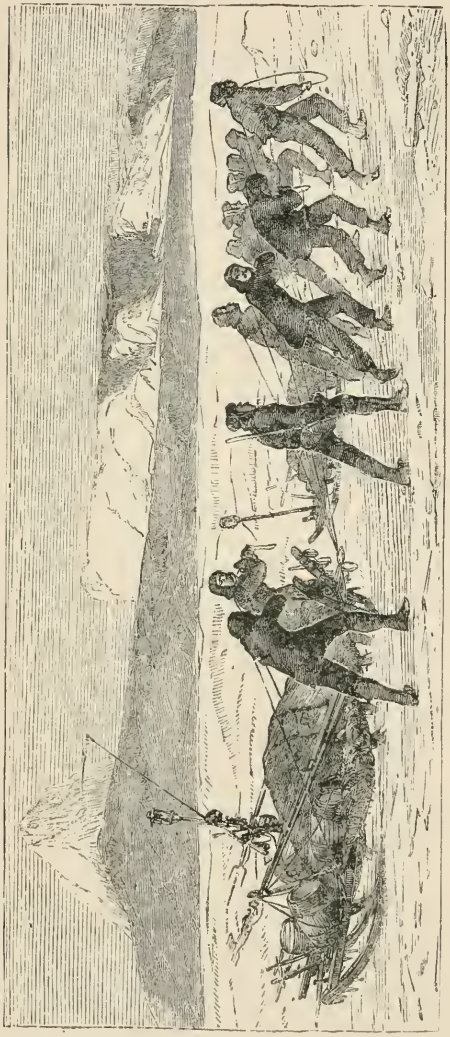
Abandoning the command to his second lieutenant, Forster, he set out in his boat-sledges, accompanied by Sir James Ross (who afterwards attained so much renown as an Antarctic explorer), Doctor Beverley, and Lieutenant Crozier (who perished, at a later date, in Sir John Franklin's unfortunate expedition). After traversing an extent of sea much obstructed by floating ice, the boats reached the limits of the last known land, the isles of Walden and Little Table. Here they loaded the sledges —which were furnished with long wooden pattens such as the Lapps use for swift journeying over the snow—with their stores and provisions; and at 10 P.M., June 24th, the expedition started, dragging the boats behind them over the ice-field.

Parry then became conscious that a great mistake had been committed. The surface before him was not the smooth and greatly undulating surface which Phipps had seen. The banks of ice were of small extent, broken up with fissures, and bristling with projections like the most rugged and irregular glaciers. More, they were frequently interrupted by pools of water, which they could not cross without launching their boats. When they halted at five o'clock, after a seven hours' march, Parry found that they had scarcely made a league.

The following extract furnishes some interesting details of this extraordinary enterprise :—

"I had conceived beforehand," says Parry, "the idea of inverting the natural order, and of marching by night in order to rest by day. There was no reason to fear the darkness of that part of the day which we call night,

because the sun does not set during the summer. And I thought that as this luminary was then very near the horizon, and shedding less light, we should not be so much annoyed by the intolerable splendour of the Polar snows, which are infinitely more dazzling than those of temperate climates. This arrangement set apart for our halts the hottest hours of the day, and gave us greater facilities for drying our clothes, often soaked by the chilly damp of those melancholy regions, or by the frequent showers which greatly inconvenienced us; more, in the colder hours the snow was firmer, and better supported the weight of the sledges. When evening drew near, we commenced our



PARRY'S SLEDGES.

preparations for departure with common prayer. We breakfasted, and attired ourselves in our travelling clothes. After five hours' labour, we gave an hour to rest and dinner; it was followed by a second march, which was frequently prolonged, for six hours. Arrangements were then made to shelter everybody in the boats; we supped, and for a short time indulged in genial amusements. While our story-tellers recited their entertaining yarns, everybody dried their clothes; sentinels were posted to guard us against the shock of ice-floes and the attack of bears; then we joined in evening devotions. Seven hours' sleep sufficed us: as soon as the hour of awaking arrived, the sound of the horn announced breakfast and departure."

On the morning of the 26th the journey was interrupted by a heavy fall of rain; and the surface of the ice-field was covered with numerous pools of water, which greatly augmented its difficulties. Under these circumstances the ice presented a singular phenomenon. It was covered with great crystals about seven inches long by an inch and a quarter broad; at some places, where they were very closely packed, they formed a kind of pavement. According to Charles Martins, who studied them at Spitzbergen, these crystals are peculiar to the Arctic Regions; they are not very regular, and remind one chiefly of the prismatic forms,—resulting from the contraction through regelation which is observable in the basalts, or those presented by clay which splits up as it dries.

Parry's calculations when, after a lapse of four days, the sun was again visible, showed a gain of not more than eight miles and a quarter. A thick snow fell, and several

hillocks could only be crossed by cutting steps with a hatchet. "Lieutenant Ross and myself," says Parry, "were always in advance. Arriving at the extremity of a field of ice, at a difficult point, we ascended an eminence of some eighteen or twenty feet to obtain a view of the vicinity. No words can convey any idea of the gloomy spectacle before us; nothing but ice and sky, and the sight of the sky often hidden from us by thick mists. Therefore, a block of ice of any singular form, or a passing bird, assumed the importance of an event; but when we perceived in the distance the two little boats and our men winding round a hillock with the sledges behind them, this sight rejoiced us, and as soon as their voices became audible it seemed to us as if these dumb solitudes had lost something of their horror. When the men had rejoined us, we returned with them towards the boats to assist in dragging them forward, for the officers took their turn with the sailors in harness. It was in this way we proceeded nine times out of ten; and even at the outset we were compelled to make three journeys to transport our stores—that is. to make the same traject five or six times.

"On the second of July the thermometer (C.) marked 1° 7′ in the shade, and 8° 3′ in the sun, spite of a dense mist; but we were so dazzled by the reflection of the light that we were obliged to halt. Under the influence of the heat the snow grew soft, and we were all compelled to harness ourselves to one boat to set it in motion. The melted snow had created large shallow pools, through which we had to drag our boats with the water up to our knees. We were unable to accomplish more than one hundred yards in an hour."

To these great difficulties must be added almost uninterrupted bad weather. A heavy rain lasted for twenty hours without a pause. On the 13th of July they found themselves in lat. 82° 17′ N., and, on the following day, after eleven hours' labour, had only gained three miles. Discovering to the north always and always the same masses of broken ice, Parry began to fear he should never arrive at the smooth ice-field on which he had relied for success. On the 20th of July, he computed that to a march towards the north, estimated at eighteen miles, corresponded a change in latitude of only seven; but he concealed this dispiriting circumstance from the crew, and continued his route. On the 24th, having obtained an analogous result, he set about demonstrating it clearly. With the greatest efforts, he gained only the difference between two opposite velocities; the ice was carried in huge masses towards the south. He then determined to return. The brave crew enjoyed a day's repose; and the officers profited by an interval of fine weather to make a series of interesting and valuable scientific observations. The brave old flag of England remained unfurled until evening; and next morning, at four o'clock, they began their journey.

On the 10th of August, the explorers found themselves in lat. 81° 40′, in the midst of a very clear sea; and launching their boats, they rejoined the *Hecla* on the 21st.

Six years after Parry's expedition, the brig *La Lilloise*, commanded by one of the ablest officers in the French navy, Lieutenant J. de Blosseville, was despatched to the same regions; but soon after reaching them, she

disappeared among the ice. The last intelligence ever received of her was communicated in a letter written by her captain on his departure from the east coast of Greenland, which he had explored over a great extent.

The principal object of the voyage of *La Recherche* was to discover some traces of the unfortunate explorers. Though in this respect, unhappily, it was not successful, its voyage was rendered remarkable by the numerous and important labours carried out by the scientific commission on board of her.

THE NORTH-WEST PASSAGE.

The route to the Pacific Ocean by the north of the American Continent has, for upwards of three centuries, been the object of the most persevering researches. In our own time it has, at length, been discovered; but the result has not been commensurate with the courageous and heroic efforts of the navigators who proposed to open up a new channel to the commercial relations between Europe and Eastern Asia. By traversing a field of compact ice Captain Sir Roderick M'Clure, after having abandoned his ship *Investigator*, which had fallen in with a mass of floating ice on the coast of Behring Strait, succeeded in regaining a ship which had entered by way of Baffin Bay into the archipelago lying north of America.

We must understand, for it is undoubtedly true, that the North-West Passage, the object of the courageous attempts of so many illustrious captains, will be always impracticable for navigation. But the exploration of this part of the Arctic Regions has furnished material for works of a powerful interest, not only by the demonstra-

tion of the assistance rendered to science by a long series of experiments and researches, but also by the example of a moral elevation, which alone could have inspired man to dare in his frail barks so many obstacles and dangers.

The principal episode in this moving history is the prolonged search for Franklin and his companions. All the maritime nations took part in this noble crusade which, by the brilliant acts of devotedness it excited, must always be counted among the most glorious events of our century. France was represented by Lieutenant Bellot, a young officer, who joined a heroic character to the eminent qualities of an accomplished seaman. He perished, in his second voyage, on board one of the ships equipped by Lady Franklin, while accomplishing a dangerous mission among the storm-shattered ice-masses. The interesting journal which he left behind him will always be regarded as a valuable introduction to the art of navigating the icy seas, and, at the same time, will furnish a powerful encouragement to well-doing. "Humanity, patriotism, and domestic affection, piety, the sentiment of duty, courage the most tranquil and unshaken, disinterestedness the most absolute, break out in a multitude of naïve and modest traits, better adapted than the most high-sounding deeds to move the soul and be taken to the heart as models."

ICEBERGS IN BAFFIN BAY.

Bellot, in his journal,* describes in a very vivid manner the icebergs his ship fell in with soon after leaving be-

* "Journal d'un Voyage aux Mers Polaires." Paris, 1854.

hind Cape Farewell, the southern extremity of Greenland :—

"A glance at the map shows that, Baffin Bay narrowing as it descends southward, the icebergs, which are first set in movement in the upper parts of the bay by the north winds, tend to accumulate in this gorge, and block up Davis Strait, even when the upper parts are free. It is only by a series of eddying and whirling movements that the icebergs finally pass this barrier, to enter the Atlantic Ocean, where they gradually dissolve.

"This mobility of the ice, necessary as it is to navigation, forms also its danger, since one finds one's-self situated between the icebergs which come from windward and the lee shore, or the solid ice which has not yet been broken up. It is useless to insist on the crushing force possessed by masses often several square leagues in extent, and which, once set in motion, can be arrested by no human resistance. A sailing-vessel finds itself in all the more unfavourable a position, because the winds blow exactly opposite to the course it requires to take in opening up the ice. Now, if the breeze be strong, we ascend with difficulty and danger into the heart of the icebergs, which form so many moving rocks; if it be calm, we can only move forward by the slow process of hauling, or by the help of tow-boats. The application of the screw-propeller to steam-ships has given them a great superiority, by doing away with paddle-wheels, which were apt to be clogged or broken by the ice.

"In the upheavals and convulsions caused by the Arctic tempests, which are very far from being so rare within the Arctic Circle as is generally supposed, the form of the

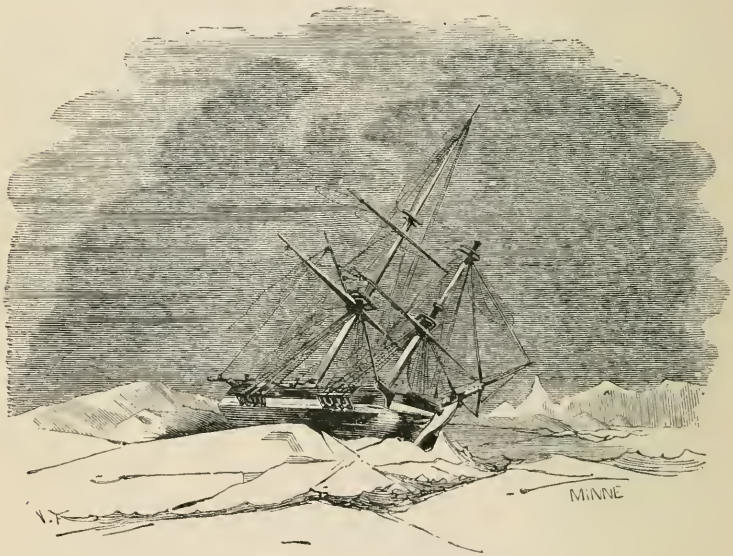
broken ice becomes very irregular; so it not unfrequently happens that at a few hundred yards before you is visible a more or less extensive sheet of water, from which you are separated only by a narrow tongue of ice. In such a case we must seek to effect an opening, either by steering the ship at full speed towards the narrowest part; or by working with saws about twenty feet long,

CUTTING A PASSAGE THROUGH THE ICE.

which are manœuvred with a cord and pulley placed at the top of a triangle formed by long poles; or, finally, by exploding a mine.

"When the ice is not too compact, we may push the ship forward into this opening, on whose sides it acts like a wedge.

"Sometimes it will happen, during this operation, that the ice, moved by the current or the breeze, closes up, after having perfidiously separated for a moment, and the vessel is then subjected to a very dangerous pressure. Woe to him who knows not how to foresee, or sufficiently observe, the signs premonitory of this accident, nearly always attended with fatal consequences. The ice, which



NIPPED IN THE ICE.

nothing checks, driving underneath the vessel, capsizes it, or sweeps over it, if it resists. I have seen plains of ice erect themselves, so to speak, along the flanks of the ship, and fall back upon the deck in blocks which the whole crew hastened to fling overboard, in the fear of sinking under their enormous weight."

In Baffin Bay, moreover, the sailor meets with great

islands of ice, detached from the glaciers of the northern lands, and particularly from the huge Humboldt Glacier, which lies on the flank of the Greenland Alps, raising itself, through Smith Sound, a little beyond 79° N. lat. Navigators have been surprised to see some of these great

ICEBERG IN THE NORTH POLAR SEA.

masses drifting in a direction contrary to that of the marine icebergs, which descend, with the Polar current, towards the Atlantic. They reascend with so much swiftness as to shatter the strata of fixed ice still adhering to the shore. Among the observations quoted on this sub-

ject by Captain Maury, is one by an experienced captain who joined in the search after Franklin; with the help of cables he painfully and slowly hauled his ship onward to encounter the current, when an enormous iceberg, coming up from the south, swept towards his ship, and after approaching it dangerously near, forged ahead with considerable rapidity. This fact is only explicable by the existence of a submarine counter-current acting on the lower extremity of the sunken portion of the mass, which, as everybody knows, is seven times larger than the visible part.

The whalers, in the course of their navigation, frequently derive considerable assistance from the icebergs. When a gale blows, they shelter themselves behind one of these floating mountains, which the wind but very slightly affects, though it sweeps irresistibly forward the masses of ice floating on the surface of the waters. A shelter of this kind may also be useful at certain stages of the whale-fishery, when rest is needful. But these refuges are not exempt from danger. Sometimes the mass dissolves at its base, and as soon as the upper part becomes heavier than the under it suddenly capsizes. Any vessel which might then be in its immediate vicinity would infallibly be crushed beneath the overwhelming weight. At other times it is carried by a current into shallow waters, where it strikes the ground, and is upset in an instant. The approach of these blocks is especially perilous when, owing to the variations of temperature, internal changes take place, which render them liable to break up into fragments. At the least shock the débris

fly in all directions, with a tremendous noise, and are capable of inflicting the most serious damages. Ships distant a hundred yards or more from the iceberg to which they had been moored, have sometimes been seriously injured

DANGERS OF MOORING TO AN ICEBERG.

by these sudden explosions. Yet our navigators are compelled to lie alongside when they are in want of a supply of fresh water. The seamen detach with their axes a sufficient number of pieces, which they melt on board; or,

if the sun has created any pools of water on the summit of the icebergs, they take advantage of them to fill their barrels.

THE OPEN SEA—ICE TRANSPORTED BY THE CURRENTS.

In very high latitudes, and beyond the dreary deserts of Arctic ice, our hardy explorers have discovered an open sea at various points. They have quitted their ships, "cribbed, cabined, and confined," amidst the snows, and, advancing in a northerly direction, have found themselves in a climate some fifteen to twenty degrees warmer. They have seen the emerald waves teeming with life, as well as the margin of the basin containing them. Innumerable birds hover in the air; the amphibia disport themselves on the shore, or on the floating ice; traces of vegetation, and even flowers, cheer and embellish the hollows and fissures where a little soil has been accumulated. In the month of May 1850, Captain Penny discovered this sea at the extremity of Wellington Strait, and, ascending the high ground, was able to detect the reflection of its waters in the sky for an immense distance. After a two years' imprisonment in the ice-bound port of Rensselaer, in lat. 78° 40′ N., where he was compelled to abandon his vessel, the American, Dr. Kane, also discovered this open sea, which is now the goal of our researches. He had despatched his second in command, Morton, to reconnoitre, in a sledge, the north of Smith Sound. When Morton had traversed some fifty leagues, he suddenly fell in with a canal in the midst of the ice-field over which he was advancing. Gradually the unencumbered surface widened, and at length a vast sheet of water, convulsed with waves,

MORTON ON THE SHORE OF THE POLAR OCEAN

stretched before him as far as the horizon, on his climbing the last cliff, Cape Constitution, in lat. 81° 20′ N. In the Asiatic section of the Polar basin, the open sea has

RENSSELAER HARBOUR.

also been sighted by the Russian officers who have explored that region.

But the open sea is not always to be found in the same localities. Thus, the passage discovered by Captain Penny was closed when he returned, a month later, with a small bark in which he had hoped to sail towards the Pole. Nevertheless, it is not impossible that some few openings

may be permanently maintained, and the existence of a sea entirely free of ice is admitted by some of our most eminent scientific authorities. This opinion may rest on the theory expounded by the eminent Italian geometrician Plana, in a paper on the Recooling of the Celestial Bodies, wherein he demonstrated that the mean heat of the year ought to be sensibly greater at the Pole than in the Arctic Circle.

Captain Maury assigns yet another cause for the existence of an open sea to the north of Greenland. He supposes that the elevation of temperature which keeps it free from ice is due to the submarine current observed in Baffin Bay, a current directed towards the Pole. This current, coming up from the south, is much warmer than the waters which it traverses, and we can easily understand that by rising to the surface it may create at the Pole a climate less rigorous than that of the surrounding regions. We may also say that the mean maximum cold of the year does not correspond to the astronomical pole, except at two points, situated the one in Eastern Siberia, and the other in the centre of the archipelago of North America.

The displacement of the ice-fields by the currents which furrow the Polar basin may also account for the periodical existence of great openings in the Arctic ice. The most powerful of these is the Gulf Stream, which conveys northward a volume of water whose heat is drawn from the Equatorial Regions, and whose influence makes itself felt as far as Spitzbergen, and even in the White Sea. Cold currents descend from the Pole along the eastern and western coasts of Greenland. In Behring Strait a surface-

current flows from north to south, while the waters of the Polar basin are carried towards the Pacific Ocean by a submarine counter-current. On the other hand, the great rivers of Asia and America, which pour their waters into this basin, must also necessarily engender there very considerable movements.

We have seen that the currents rapidly transport the ice-field of Parry towards the south. The English ship *Resolute* traversed a space of one thousand miles on an ice-field not less than three hundred thousand miles square, from the midst of which its crew had been unable to disengage it. Captain Kellett had abandoned it at Melville Island some years before it was found in Baffin Bay by the whalers. In Davis Strait, Lieutenant de Haven, who commanded the American brig *Advance*, despatched to join in the quest after Sir John Franklin, was detained for nine months in a similar position, and likewise drifted a thousand miles towards the south.

In studying the circulation of the Arctic Ocean in its relation to the movement of the ice over a considerable extent, around Spitzbergen and Novaia Zemlaia, Captain Jansen, an able Dutch officer, of remarkable scientific attainments, has shown how the combined action of tides and currents intervenes in the dislocations and breakings-up of the Polar ice-fields which occur principally in the spring, but sometimes also in the midst of winter. According to Jansen, the few spaces left by the ice-fields, when they are carried southward, may have been mistaken for the open seas supposed to have been discovered by Penny, Kane, and others.

EXPEDITION TO THE NORTH POLE.

Of late years, our men of science and navigators, stimulated by the discoveries already made,—discoveries, it must be owned, of a sufficiently extraordinary nature,—have elaborated various projects of Arctic exploration. Geography, the physics of the globe, the natural sciences as well as the great fishing industries, are keenly interested in their realization; and it is to be hoped the governments of the principal maritime nations will soon confide the charge of new expeditions to the tried and experienced officers who ask permission to return to a region already illustrated by so many glorious enterprises, and complete its conquest by planting at the Pole itself a victorious flag.

Dr. Hayes, the friend and fellow-traveller of Kane, made an attempt to carry out this great object, in 1860 and 1861, basing his plan of operation on the discovery of the open sea made by Morton, to the north of Smith Sound. He hoped to winter in Grinnell's Land, in or about the 80th parallel of north latitude; and thence, as soon as spring returned, to make for the unknown waters, by crossing the ice-blocks of the canal in a boat mounted upon wheels. The expenses of the expedition were defrayed by a public subscription raised at New York. Unfortunately Hayes, during his voyage, met with a succession of unfavourable accidents; his vessel was delayed by storms, and seriously damaged by icebergs. He did not even succeed in reaching Rensselaer Harbour; and an epidemic breaking out among the dogs procured by the Eskimos, their number diminished to such an extent that

he was compelled to renounce his scheme, for the execution of which they were indispensable.

Early in 1865, Captain (now Rear-Admiral) Sherard Osborn submitted a somewhat similar project to the Royal Geographical Society, but one better adapted to the nature of the region he proposed to explore. Our gallant adventurer, who, when taking part in the search after Franklin, had accomplished 1180 miles in a sledge, proposed to adopt the same method of travelling, for he did not believe that the ice would be permanently open beyond Cape Constitution. Numerous examples are on record of long journeys accomplished in sledges. In M'Clintock's expedition, when he discovered the Franklin relics, he made about 900 miles in one hundred and five days; and he calculates that 1180 miles are not beyond the strength of energetic and resolute men. Now, to reach the confines of the furthest land known at the Pole, and again return, is but 950 to 1000 miles.

Captain Osborn's scheme requires for its fulfilment a couple of small screw-steamers, with one hundred and twenty men and officers. In August they would reach Smith Strait; one ship would remain, in charge of twenty-five men, at Cape Isabella, lat. 78° N.; the other, with ninety-five men, could advance about 300 miles to the north. After having established depôts of provisions at the greatest possible distances during the autumn, the explorers would have two years before them to undertake their sledging expeditions at the most favourable epochs.

The plan propounded by the great German geographer,

Dr. Petermann, in a congress of scientific men and seamen, held at Frankfort in 1865, and submitted, soon afterwards, to the Royal Geographical Society, selected a point of departure near the eastern coast of Greenland, and also proposed the employment of a couple of steam-vessels. Dr. Petermann founded it on the experience of several navigators, who, instead of finding, as Barentz and Hudson did, a compact bank of ice in the region lying northward of the island, have penetrated into an open sea. Traditions long preserved among the Dutch whalers attribute to a certain number of these hardy mariners the most fortunate voyages in this respect. Their customary fishing-ground lay close to the 80th parallel, and they found there very little ice; one of them ascended as high as 82° 10′, and met with only a few icebergs. Cornelius Roulé pretends that he reached 85° on the meridian of Novaia Zemlaia, and visited in these remote regions several islands peopled by flocks of birds: he adds, in his extraordinary narrative, that having ascended to the summit of a hill, the sea which lay before him seemed sufficiently open to admit of a three days' voyage. We do not know, it is true, whether implicit confidence can be safely placed in these ancient documents; but, at all events, we may rely on the careful observations of Dr. Scoresby, whose important scientific researches justify us in entitling him the "Saussure of the Polar Regions."

On the 24th of May 1806, this navigator, finding himself to the north of Spitzbergen, in lat. 81° 30′, discovered the sea entirely open for an extent of 30 miles; and he calculated that for a distance of at least 100 miles no land would be encountered. "Had our voyage," he adds, "been

a voyage of discovery, we should certainly, by advancing northward, have added something to the geographical knowledge of the Arctic Regions; but the fishery was our sole object, and my crew, in the midst of these unknown and desolate regions, were painfully impressed, and showed signs of discouragement."

In case the vessels of his proposed expedition should not meet such favourable circumstances, Dr. Petermann thinks they might make an attempt similar to that which Sir James Ross accomplished so successfully in the Antarctic Regions; that is, might endeavour to force the ice-field at a carefully chosen point. Wintering at Spitzbergen, which, in spite of the rigour of the climate, is actually feasible, would greatly facilitate the expedition, and care would be taken beforehand to lay up in that island a sufficient store of coal.

At the meetings of the Royal Geographical Society, the two projects were the theme of an interesting discussion, in which nearly all the officers of our navy who may claim to be designated *Arctic* officers took a part. Though they founded their judgments on the personal experience acquired in voyages of discovery, very great divergences of opinion were manifested, and the balance could not be said to incline in favour of one project more than the other. Several members suggested that a simultaneous effort should be made by both routes, the Spitzbergen and the Smith Strait.

Lady Franklin, the widow of the illustrious navigator,

furnished a touching proof of her sympathy with a new Polar expedition, in a letter addressed to Sir Roderick Murchison, the late president of the society. Claiming for England as her right whatever glory was yet to be acquired in a region where her seamen had braved so many dangers, and endured such terrible sufferings,—"I have ever the same interest," she continued, "in everything relating to Arctic enterprise. At first, in the sad remembrance of the past, I have felt my heart sink, but I have struggled against this feeling, and have triumphed over it. It would be certainly deplorable to see any powerful objection to all future Arctic exploration in the fate of my dear husband and his companions. They met with the unfortunate end which too frequently befalls the pioneers of dangerous enterprises, but their sad destiny is unique. Each new expedition starts with better ships, better equipped, and with increased scientific knowledge. The Polar seas do not on an average present more catastrophes than any other seas, and in the projected expedition a disaster like that of Franklin's is not to be apprehended."

Dr. Petermann's project met with enthusiastic supporters in Germany; a public subscription, opened for the purpose of realizing it, produced a considerable amount. The Academy of Sciences of Berlin, at the invitation of the Prussian government, which defrayed a portion of the cost of the expedition, drew up a programme of the scientific problems it ought to solve. But notwithstanding the zeal and gallantry of the commanders of the expedition, which consisted of two ships,—the *Ger-*

mania and the *Hansa*,—the actual result obtained was very trivial, and the open sea was not reached. Another attempt will be made this year (1875) by British seamen, under the auspices of the Admiralty; and we should rejoice if the "conquest of the North Pole" was effected at last by British perseverance.

Although from the last land known to the north of Behring Strait—namely, Herald and Plover Isles—the distance to the Pole is double the distance from Spitzbergen, this route has been proposed by an officer of the Russian marine, M. von Schilling; and, in France, by a hydrographic engineer, M. Gustave Lambert, patronized by the *Société de Géographie*. The latter bases his scheme on the existence of an open sea around the Pole, into which the voyager would penetrate after a short passage within the ice-field, by selecting a point of attack in longitude 180°. It was in this neighbourhood that Wrangel and D'Anjou, in their voyages of 1820 and 1823, discovered the vast extent of open water which they designated by the name of *Polynia*.

For the convenience of our readers, we tabulate the principal expeditions which have been engaged in the search after the North-West Passage :—

Sir Martin Frobisher, 1576.
Captain John Davis, 1585.—Discovered Davis Strait.
Barentz, 1594.
Captains Weymouth and Knight, 1602.
Henry Hudson, 1610.—Discovered Hudson Bay.
Sir Thomas Bultow, 1612.
William Baffin, 1616.—Discovered Baffin Bay.

Foxe, 1631.

Middleton, 1746.

John Hearne, overland, 1769.

Captain Phipps (Lord Mulgrave), 1773.

Captain James Cook, 1776.—In the *Resolution* and *Discovery*.

Mackenzie, 1789.—Discovered mouth of Mackenzie River.

Captain Duncan, 1790.

Captain Vancouver, 1793–95.—In the *Resolution*.

Lieutenant Kotzebue, 1815.

Captain Buchan and Lieutenant Franklin, 1819–22.—In the *Dorothea* and *Trent*.

Captain (Sir James) Ross and Lieutenant (Sir John) Parry, 1818.—In the *Isabella* and *Alexander*.

Lieutenants Parry and Lindon, 1819.—In the *Hecla* and *Griper*.

Captains Parry and Lyon, 1821.—In the *Fury* and *Hecla*.

Captain Parry, 1824.—In the *Hecla*.

Captain (Sir John) Franklin and Captain Lyon, 1825.

Captain Sir John Parry, 1827.—In the *Hecla*.*

Captain Sir James Ross, 1833.—After an absence of nearly four years.

Captain Back, overland, 1835.—Explored the Great Fish River.

Captain Back, 1836.—In the *Terror*.

Captains Sir John Franklin, Crozier, and Fitzjames, 1845.—In the *Erebus* and *Terror*. Franklin died June 11, 1847; no traces of him or his companions were discovered until July 1854.

Commanders Collinson and (Sir Roderick) M'Clure, 1850.—In the *Enterprise* and *Investigator*, in search of Franklin.

North-West Passage discovered by Captain M'Clure, October 26, 1850.

Captain W. F. Hall, 1868–73.

German expedition, the *Hansa* and *Germania*, 1872–73.

Austrian expedition, under Lieutenant Payer, 1873–74.

EXPEDITIONS IN SEARCH OF FRANKLIN:—

Captains Moore and Maguire, in the *Plover*, 1848.

Sir J. Richardson and Dr. Rae, overland, 1848–51.

Sir James Ross, 1848–49.

Captain Kellett, 1848–51.

* Arrived within 435 miles of the North Pole.

Commander Saunders, 1849-50.

Captains Austin and Ommaney, and Lieutenants Cater and Osborn, 1850–51.

Captain Penny, 1850–51.

Lieutenant De Haven and Dr. Kane, 1850-51.

Sir James Ross, 1850–51.

Sir Edmund Belcher, Captain Kellett, Captain Pullen, and Captain Osborn, 1852–54.

Captain Forsyth, 1850; Mr. Kennedy and Lieutenant Bellot, 1851–52; Commander Inglefield, 1852; Mr. Kennedy, 1853.*

Dr. Kane, 1853; and again, 1855.

Inglefield and Bellot, 1853; Dr. Rae (discovers relics), 1854.

Inglefield, 1854.

Sir F. L. M'Clintock (discovers skeletons, &c.) 1857–59.

* These four expeditions were equipped by Lady Franklin and her friends.

IV.

Conclusion.

CHANGES OF TEMPERATURE—GENERAL LAWS.

WE have already demonstrated the usefulness of glaciers from the point of view of the general circulation of the waters and the irrigation of the plains, which they fertilize in the season most favourable for their cultivation. We know that rivers under the influence of glaciers swell in the summer, and sink during the winter. And it is evident that the hotter the summers, and the greater the dryness, the more will the fusion of the accumulated ice and snow augment the springs and swell the flowing brooks. Nature invariably works by grand and simple laws. The glaciers send down to the ocean the great rivers and immense masses of floating ice which help to maintain it at a permanent level. The geographical distribution of these powerful reservoirs depends, as we have seen, upon different causes, such as the direction of the mountain-chains, their elevation, the escarpment of their slopes, their situation on the sea-margin, or in the interior of the continents. The temperature, the direction of the prevailing winds and their habitual degree of dryness or humidity, are also in

intimate connection with the extent and position of these chains. But, from the lofty peaks of Switzerland, and the Cordilleras, even to the Polar Regions, which may be considered as immense glaciers, the beneficent action of the reservoirs of ice and snow in the present period is everywhere conspicuous; just as it was in the primeval world, when their prodigious development prepared a vast field of activity for mankind.

The following considerations, due to Dr. Buist, one of the scientific collaborateurs of Captain Maury, indicate some of the relations whose beauty and usefulness impress our understanding, whenever we devote ourselves to an enlightened contemplation of the wonders of Nature :—

"The sun constantly developing in the Equatorial Regions a considerable quantity of heat, of which the Polar Regions are deprived, owing to their exposure, to render all these regions inhabitable by creatures of the same organization a continual interchange of cold and heat from one to the other is requisite. And, in effect, this actually takes place, and we see it operating in a wonderfully simple manner: in the neighbourhood of the Equator, the heated air expands and rises, leaving near the earth a comparative vacuum which the surrounding air rushes in to fill: thence result, on the surface of our globe, two aërial currents directed from the Poles towards the Equator, while, in the upper regions, the dilated air extends, in virtue of its dilatation, towards the Poles, where it cools and retracts; and thus we have at work two immense whirlwinds, whose effect is to carry off from the torrid zones an excess of heat which will warm the frozen zones, at the same time that the latter

will bring back the cold air intended to refresh the Tropical Regions.

"The same laws of movement would determine an analogous system of circulation in the liquid mass of the immense ocean, if other influences did not come into play, and the various continents did not interpose their barrier;

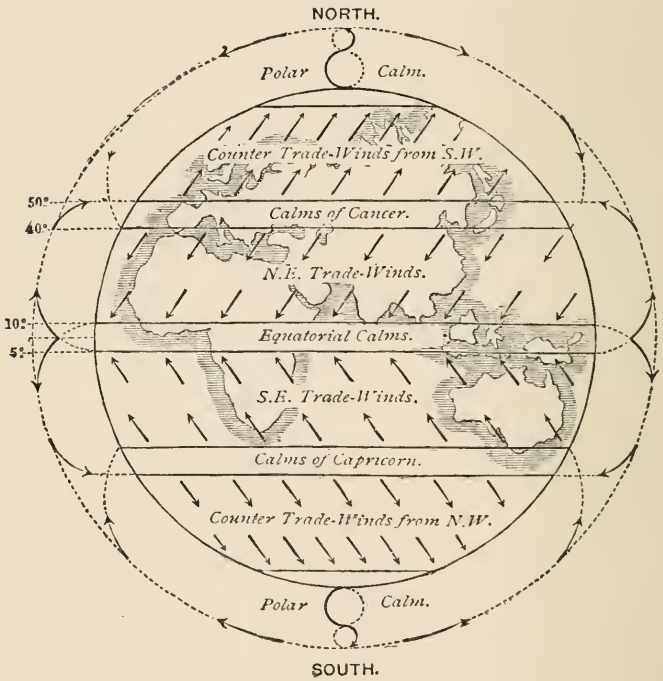


CHART OF AERIAL CURRENTS.

nevertheless, we shall find there certain currents directing themselves constantly from the frozen towards the torrid zones, with the view of replacing the enormous quantity of water carried off from the latter by evaporation; while, at the same time, other currents—as, for example, the Gulf Stream—equally participate in this vast interchange of

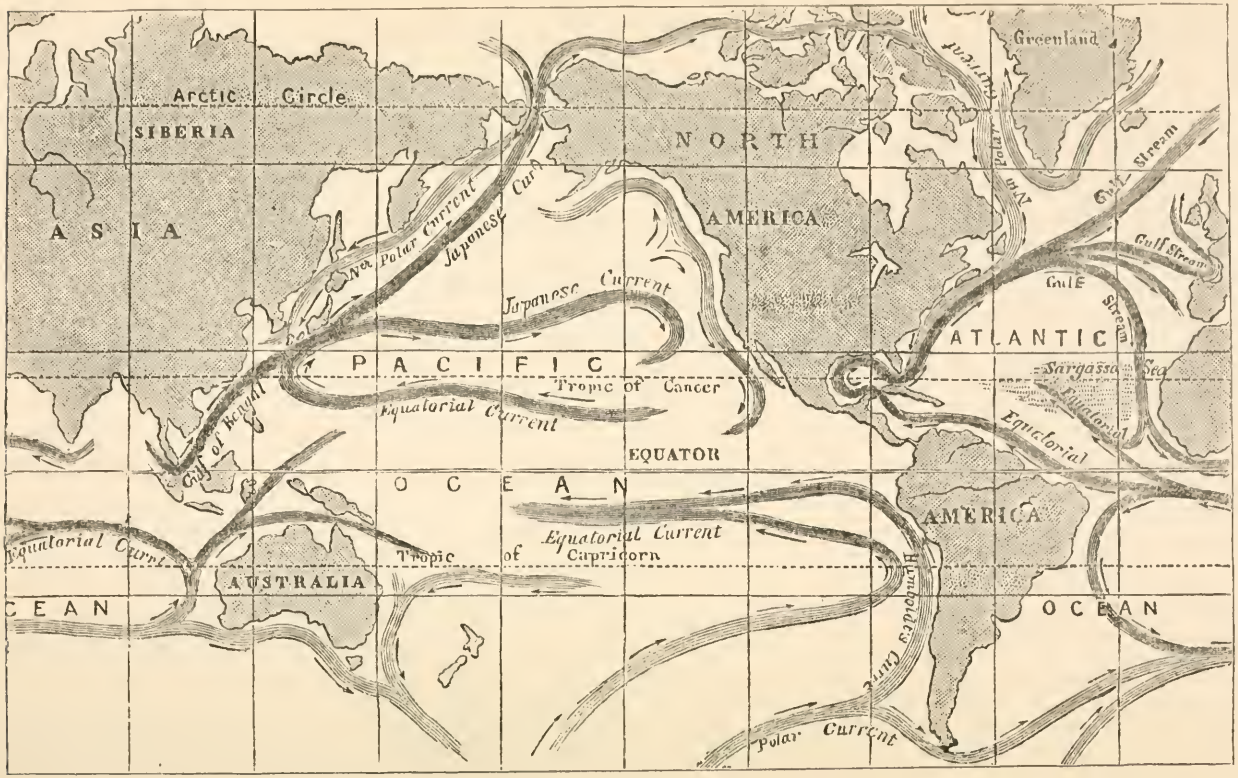


CHART OF MARINE CURRENTS.

temperature. This mighty ocean-river, of a temperature notably superior to that of the waters surrounding it north of the Tropic, warms all the lands which it approaches; and thus permits the Lapp to cultivate his fields of rye in latitudes which, without this influence, would be condemned to a perpetual sterility.

"Other laws there are which govern the sea, from the point of view of the interchange of temperatures. Thus, we know that water attains its maximum of density at 4° above zero; and it is owing to this property that the Polar seas are not converted into a mass of solid ice, inaccessible to ships. In fact, this water at 4° tends to sink by the mere fact of its density, while preserving its temperature, and proceeds to undermine the base of the monstrous glaciers of the Pole, which, being thus uprooted, are carried away by the currents that conduct from the Poles to the Equator the water destined to compensate for the evaporation of the torrid zone. One can conceive what an enormous quantity of water is borne towards the Equator with these floating masses, which frequently have a superficial area of not less than six square miles.

"All these great physical laws, admirable as they appear to us, are, nevertheless, but a feeble specimen of the processes which Nature employs to work out her beneficent ends. Thus: these variations of climate, which we see dispersed in gradation along the surface of the earth, between the Poles and the Equator, we also encounter at elevations varying from 3000 to 21,000 feet; which, in the torrid zone, answer to about two-thirds of the height of certain mountains. In America, from the

Equator to the Tropic of Capricorn, and probably also in Africa, between the same parallels, are lofty chains of mountains, their summits crowned with perpetual snow, which strike due north and south, and are found only on the route of the Trade Winds. An analogous chain, but of smaller dimensions, traverses the peninsula of Hindustan, and rises, as it approaches the Equator, to an elevation of 8000 feet at Dodabetta, and nearly 6000 in Ceylon. In an inverse direction—that is, from east to west—we have in Europe the Alps, and in Asia the gigantic peaks of the Himalaya; both sufficiently far towards the southern boundary of the temperate zone, and situated on the traject of the aërial currents. Finally, other and less important chains in the direction of the parallels or the meridians, or in an intermediary direction, rise everywhere along the route of the atmospheric currents, and renewing to some extent the provision of cold of those masses in movement, receive in exchange the heat of which they are in want."

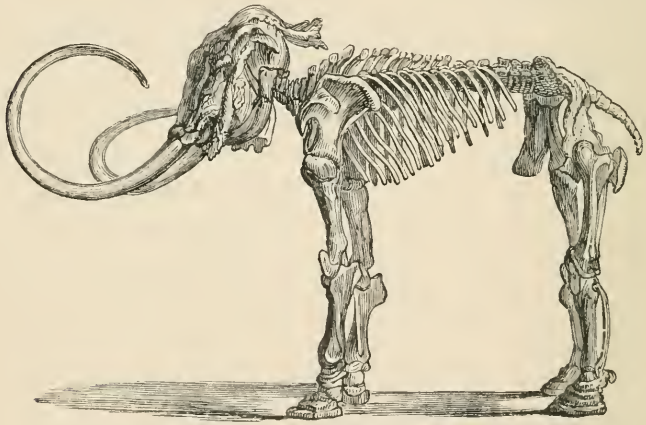
Such are the wonderful results separately produced by the ocean and the atmosphere; results more admirable still when these two agents concur in an interchange of temperature. But we might easily, without straying from our subject, multiply tenfold our examples of the harmonious general laws which prevail on the surface of the globe, and maintain there both life and motion.

THE FOSSIL MAMMOTHS—A FOSSIL GLACIER.

We have set forth in a summary manner the principal discoveries due to the researches of contemporary men of

science into the phenomena of glaciers ; and have pointed out the hypotheses proposed in explanation of their ancient extension. Though these hypotheses rest on a great number of incontestable facts and positive theories, they are as yet surrounded with many uncertainties ; and it will be enough for us to sum up some recent observations to show the importance of the problems as yet unsolved, and the rare interest of studies which offer a rich harvest to future investigators.

We know that the bones of the mammoth or fossil



SKELETON OF THE MAMMOTH.

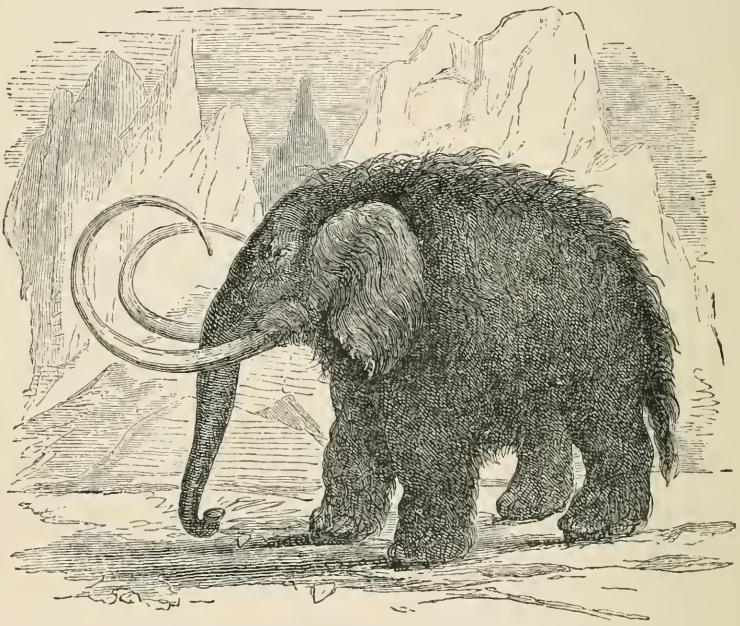
elephant have been met with in great abundance throughout that part of Siberia which extends from east to west, from the limits of Europe to America, from the base of the mountains of Central Asia to the shores of the Arctic Sea. In this vast area, on the banks of the Irtish, the Obi, the Yenisei, the Lena, and other rivers, fossil elephantine remains are almost everywhere obtainable. The islands of the Polar Sea contain such extraordinary quan-

tities, that the declivity of the Isle of Bears is formed of hills almost wholly composed of the bones of mammoths. To give an idea of this prodigious mass, we may add that from 60,000 to 80,000 pounds of ivory are annually drawn from Northern Siberia, and from the island-group of New Siberia. Now, as the mean weight of a single tusk does not exceed 120 pounds, this quantity of ivory will represent at least 650 individuals; and as the work of exhuming them has been going on for many years, we may judge how enormous must have been the accumulation of mammoth remains in these districts, where they are frequently accompanied by the bones of the rhinoceros and the Siberian buffalo, or bison.

In 1772, Pallas discovered at Wiljuiskoi, in lat. 64° N., on the banks of the river Wiljui, an affluent of the Lena, the body of a rhinoceros which had remained for centuries in a state of congelation, and might be compared to a natural mummy. We have already spoken of the discovery, made thirty years later, of the whole body of a mammoth, which had been embedded in a mass of ice on the banks of the Lena, and whose softer parts were so well preserved that wolves and bears fed upon the flesh. The animal's skin was covered with black hairs, like those of a boar, and these hairs were twelve to sixteen inches long. And, in addition, it was clothed in a reddish wool, about an inch in length. This mammoth was nine feet in height by sixteen feet in length, without taking into the account its colossal tusks. Its skeleton figures in the Museum of St. Petersburg.

The discovery of a mammoth, with bones and flesh complete, is not an unique fact; and we may cite on this

subject the following interesting passage from the "Voyage" of Isbrant-Ides, a German established in Russia, who was despatched on an embassy to the Emperor of China in 1692 :—"In the mountains situated to the north-east of the river Keta are found the tusks and bones of the mammoths : they are also discovered on the banks of the river Yenisei, the rivers Trugan, Mungazea,



THE MAMMOTH—RESTORED.

and Lena, in the vicinity of the town of Jakutskoi, and as far as the Frozen Sea. All these rivers, in the season of the thaw, bring down huge blocks of ice with such impetuosity as to carry away mountains, and roll onward prodigious masses of earth. The inundation at an end, these masses of earth remained up-piled on their banks,

and the dryness causing them to split open, mammoth tusks, and sometimes whole mammoths, are found in their interior. A traveller who accompanied me to China, and who went yearly in quest of mammoth tusks, assures me that he discovered, on one occasion, in a heap of frozen earth, the whole head of one of these animals, whose flesh was corrupted; the teeth projected from the muzzle like those of elephants, and it was with difficulty he and his companions extracted them, as well as some bones of the head, and among others that of the neck, which was still tinted with blood; finally, having continued his explorations of this same piece of earth, he found there a frozen hoof of monstrous dimensions, which he carried to the town of Trugan. This foot, he told me, was as large and round as the waist of a tall and robust man.

"On the subject of these animals the people of the country hold very different opinions. The idolaters, such as the Yakuts, the Tungusians, and the Ostiaks, assert that the mammoths dwell in very spacious subterranean galleries, from which they never emerge; that they wander to and fro in these galleries, but, as soon as they pass beyond, the upper part of the cavern rises, and then sinks suddenly, so as to form a profound precipice. They are also persuaded that a mammoth perishes as soon as it sees the light, and they maintain that in this way those have perished which are found dead on the river-banks near their underground habitations, whither these animals inconsiderately wander.

"The old Russians of Siberia believe that mammoths are simply elephants, though the teeth which they find

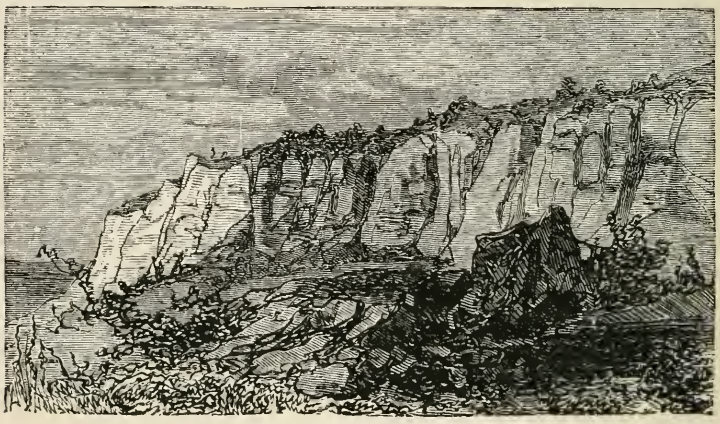
are somewhat more bent and more closely set in the jaw than those of the latter animals. Before the deluge, they say, the country was very warm, and the elephants floated in great numbers on the waters until they subsided, and were afterwards buried in the mud. The climate having turned very cold after this great catastrophe, the mud froze, and with it the bodies of the elephants, which are thus preserved in the earth uncorrupted until the thaw reveals them."

As it was a matter of extreme interest to observe in the carcass of one of these elephants the arrangement of the organs and the contents of the stomach, the Academy of St. Petersburg, on the proposition of one of their number,—M. de Middendorf,—offered a prize for the discovery of a complete mammoth's body, if information of the discovery were forwarded in time to make it available. In December 1865, the Academy received intelligence that a Samoyed had found a perfect mammoth, with its skin intact, near the bay of the Tas, which opens into the Gulf of Obi. The Academy immediately issued the necessary instructions, and intrusted with a special mission the well-known geologist, F. Schmidt. It was his intention to profit by the usual winter routes in order to push forward as far as Ochotskoje, in lat. 70° N., and there to wait until the snows melted before he went in quest of the mammoth. No narrative of the naturalist's journey has yet been published, but we hope that when it sees the light it will considerably increase our knowledge of the mammoths, those curious witnesses of primeval ages, whose number, in all probability, far exceeded that of all the elephants now living.

All known facts encourage the belief that this species, indued in a thick shaggy fur, was endowed by nature with all that was requisite for its endurance of the rigorous winters of a climate which, however, was able to produce the vegetation necessary for its nourishment. Sir Charles Lyell, in reference to this subject, observes, that in spite of the excessive cold at present prevailing in the eastern regions of the Asiatic Continent, forests of firs are to be found there, and woods of birches, poplars, and elms, which advance along the Lena, as high as the sixtieth parallel of latitude. Under the Polar Circle, where the forest trees are succeeded by dreary and stunted bushes, mosses and lichens, the food of the reindeer, everywhere cover the rocks. Mushrooms and ferns, several species of saxifrage, and various other plants are developed there with a surprising rapidity in the first bland days of summer, on the light stratum of soil which, in some sheltered valleys, covers the ice, and offers a striking contrast, frequently described by travellers, to the gloomy aspect of a region where winter never abandons its empire.

In Kotzebue Bay, to the north-west of Behring Strait, Dr. Seemann, the distinguished naturalist, observed, in 1850, a very remarkable glacier. Above the terminal escarpment of the glacier, our English seamen saw with surprise a thick argillaceous mass, some four to twenty-one feet in depth, resting immediately on the ice ; over it lay a bed of turf, bearing a luxuriant vegetation of brushwood, of willows, heaths, and herbaceous plants intermingled with mosses and lichens. This peat-bed, covering a glacier, affords a kind of geological date. It shows that the ice must be several centuries old. But more: in

the portions of argillaceous earth which have slipped, Seemann and his companions collected numerous bones of the elephant, horse, reindeer, and musk-ox. One of the elephant's tusks was thirteen feet in length, and weighed upwards of one and a half cwt. We must not forget that this elephant or mammoth is a fossil animal; an extinct species no longer to be found alive in the northern hemisphere. This ice, therefore, was contemporary with the elephant,



A FOSSILIFEROUS GLACIER.

or even anterior to it; and hence the glacier cannot belong to the present epoch, but to the age when the ice of the North as well as of our own European mountains extended over a great part of Europe and America; it is a *fossil glacier*. The waters, resulting from the fusion of the snows, have deposited on its surface the stratum of clay,—which, in all probability, is simply the impalpable mud produced by the ice grinding against rock and crag, —and, at the same time, drifted along the bones of elephants, reindeer, and musk-oxen which had perished

in the vicinity. On this ever damp clay some mosses speedily established themselves; these, in time, were converted into turf, or peat, which was covered, in due time, with the vegetation peculiar to it. Protected by its superincumbent stratum of earth, the ice has never melted, even superficially, but has been preserved, like the hardest rocks, from the atmospheric influences.*

To explain the presence of mammoths and other extinct quadrupeds in the Polar Regions, it is necessary we should point out that the animals of the northern climates migrate according to the seasons. For example, the musk-ox generally abandons its winter-quarters, and traverses the sea on its icy surface to pasture, during the summer, among the herbage of Melville Island, which is situated in lat. 75° N. We may then admit that the mammoths might also extend their excursions towards the Arctic Circle; and, in this case, the preservation of their bones, and even of their whole body, in the ice or in the frozen soil, may be explained, without its being necessary to assume any sudden revolution, either in the primeval climate, or in the primitive condition of the surface of the globe. We may here sum up the considerations put forward by Sir Charles Lyell in support of this opinion. There is reason to suppose that at the epoch when the mammoth lived, the low lands of Siberia did not extend so far northward as at present. The facts ascertained by Wrangel have proved, moreover, that a gradual upheaval of the soil, analogous to the movement taking place in a part of Sweden, Norway, and Greenland, has also been in

* Martins, "Les Glaciers et la Période Glaciaire."

operation along the coasts of the Frozen Sea. Such a change in the physical geography of that region implies the continual extension of the Arctic lands, and would tend to augment the intensity of their winter; and it is rather to this augmentation than to a general diminution of the present mean temperature that we must attribute the extinction of the mammoth and its contemporaries.

On the other hand, the great rivers of Siberia, flowing from Temperate towards Arctic Regions, are all, like the Mackenzie in North America, subject to considerable inundations; caused, as we have shown, by the floods occurring in the upper part of their course. Hence, they are completely frozen in winter for an extent of several hundreds of miles in the neighbourhood of their embouchures. In this state of things, the running waters expand over the ice, and frequently change their direction, carrying with them enormous quantities of earth and of gravel mixed with ice. Now, the Siberian rivers being among the greatest water-courses in the world, it is easy to conceive that the animals drowned in their depths may be transported to very great distances in the direction of the Arctic Sea, and during this traject may become embedded in the floating ice or frozen mud. According to Professor Baer of St. Petersburg, the earth is always in a frozen condition to a depth of about 390 feet, at Yakutsk, a town situated on the western bank of the Lena, in lat. 62° N., and distant upwards of 200 leagues from the Polar Sea. We can understand that in such a region the bodies of animals embedded in the ice and mud may remain there indefinitely, without being stricken by putrefaction. These bodies may also have been engulfed

under some huge mass of snow, transformed into compact ice, which the currents have drifted towards the Polar Regions.

To conclude: everything induces us to believe that the mammoth, like other quadrupeds adapted to a life in high latitudes, was able to inhabit the northern parts of Asia, at an epoch when the climate was milder and more uniform than it is at present.

VARIATION OF CLIMATES.

The questions originated by the variation of the climates of the globe have engaged the attention of a great number of physicists. In searching into the causes which may have determined the rising or sinking of the temperature in the primeval world, one is also led to ask whether the general thermometrical condition has changed since historic times, or if it is changing now. We shall avail ourselves here of some interesting particulars from M. Reynaud's remarkable "Note sur la Variation Séculaire des Climats," in which this problem has been boldly discussed, and which, moreover, furnishes much new information on the glacial period.

In the paper to which we refer, our readers will find indicated a general theory of the two orders of seasons which prevail in every planet, depending on the secular variation of the astronomical elements. According to this theory, it was 11,760 years before our era that the hot and cold seasons presented in our hemisphere, so far as the solar heat is concerned, the maximum of their difference; that is, the most favourable circumstances for an extraordinary extension of the glaciers—a short and hot

summer alternating with a long and severe winter. In fact, the sun, by yielding in summer only the same total quantity of heat, perceptibly determines the fusion of the same quantity of ice; while, on the contrary, the quantity of ice annually formed augments in proportion to the length and severity of the winters.

In 1122 of our era the difference in question had, on the contrary, reached its minimum; and since that date our hemisphere advances anew towards the maximum of contrast, while an opposite effect is taking place in the southern hemisphere, which finds itself in an inverse position relatively to the variation of the general character of the seasons.

"It suffices," says Reynaud, "to turn to the chronicles of the northern nations for proofs that the Arctic glacier has exactly followed a progression in conformity with the laws whose effects we are endeavouring to distinguish. About the tenth or eleventh century, the Scandinavian navigators discover an open sea on the east coast of Greenland; there they establish themselves, and found colonies, which prosper, and continue in connection with Europe; then, towards the fourteenth century, the sea is closed, the prolongations of the Polar glacier extend along the coast as far as its southern extremity; communications are interrupted, the country becomes depopulated, and the Arctic spirit resumes possession of a region which she had abandoned but a few centuries before,—that is, some time in the twelfth.

"Here is an indisputable fact which we may be permitted to consider as a proof that our planet is really

sensible to the secular variation of the seasons. Moreover, it perfectly agrees with the change of climate known to have taken place in Iceland and the island of Jan Mayen, as well as in the north-western archipelago, where various traces show that the population of the Eskimos is driven year by year from its ancient stations, and compelled to redescend towards the south."

The glaciers ought to offer the same kind of verifications; and the observations of a great number of naturalists seem, in fact, to prove the progression of the glaciers in Switzerland. In the southern hemisphere, the great Polar glacier would appear, at the same time, to be diminishing, as Reynaud's theory indicates. The route pursued by Cook, who coasted along the ice-field as near as possible, is very different from those which conducted Sir James Ross and Dumont d'Urville to the discovery of the Antarctic continent.

The limited space to which we are necessarily restricted in these pages does not admit of our entering into a full explanation of a theory dependent upon abstruse mathematical analysis. But, in confirming and approving it, calculation, so far as the present condition of the physical sciences allows, agrees with reasoning and observation. This theory, moreover, according to its author, does but approach, not actually accomplish, a solution of the problem, the difficulties of which increase if we undertake to examine it as a whole; that is, by adding the heat-action of the sun to the heat-action of the planet.

Adhémar, in his great work on the "Revolutions of the

Sea," and the periodical occurrence of tremendous deluges, adduces certain leading principles or laws of nature to account for the phenomena which have successively modified the configuration and structure of our globe.

His explanation is based on the same principles of which we have endeavoured to give the reader an idea; but he curiously exaggerates their consequences. In fact, he seeks to prove that our earth's centre of gravity may be displaced by the accumulation of ice at one of the Poles:—

"Since the year 1248," he writes, "our atmosphere has begun to cool, while in the southern hemisphere it has been growing warmer; and when the ice-masses of the North Pole shall exceed those of the South, the centre of gravity of the terrestrial system will traverse the plane of the Equator. The world of waters will be swept from one hemisphere to the other, and the continents adjacent to the Antarctic Pole will be abandoned by the sea, while those which we inhabit will be overwhelmed beneath it."

Let us hope this alarming change of the "centre of gravity" will not take place in *our* time, or in that of our children! Yet we cannot help imagining what a theme it would afford for the glowing pen of the "Special Correspondent."

It would not be impossible, according to this daring speculator, to detect the actual enlargement of the Antarctic glacier, if we made a careful observation of the shadow of the earth on the occasion of a lunar eclipse. He reminds us that, in June 1830, M. d'Abbadie, when studying at London the remarkable *icy hood* or *crest* of the planet Mars, found the phenomenon of so remarkable a character that he made a drawing of it, in which the

planet is seen to be plainly pointed in one side. Now, different astronomical conditions ought to produce, in Mars, a very great inequality in the glaciers of the two Poles.

We shall dwell no longer upon these extravagant theories; but as they have been put forward by earnest and able men, with so much learning and science, we felt it our duty to place their outlines before our readers. But we may add that if, before entering upon a new age or period, the earth must again undergo a cataclysm similar to the convulsions which marked the earlier stages of its formation, it will undoubtedly be permitted us to hand down to our descendants the treasure of moral and scientific truth which is the result of the labour, the enthusiasm, the genius of so many great and good men, the most incontestable proof of our divine origin, and the most certain pledge of a destiny in accord with the Christian's faith and the grandeur of his aspirations.

This faith and these aspirations are, as we know, the real source of all great and permanent progress in our civilized and enlightened communities. If genius and science, opening up to naturalists an unknown world, have commenced the marvellous history which will enable us eventually, with the assistance of the laws of geology, to ascend to the most distant epochs of the terrestrial creation; if they have recovered traces of successive phenomena produced by the Creative Power; we ought to remember that this has been effected, not only by carrying into difficult researches the exact method which fertilizes observation, but also by consecrating to these researches the energy of a sincere devotion and of a moral elevation, the influence of which we shall always detect

in the work of the chosen minds that have done honour to our race by their intellectual daring and generous sympathies.

The full force of this double impulse has been eloquently described by the naturalist Tschudi :—

"The attraction which leads man towards the regions of the North is the sentiment of moral and intellectual power so predominant in his heart, and so valuable in the maintenance of his energy before the terrible obstacles with which Nature everywhere excites it; is the satisfaction of triumphing, by the persevering efforts of an intelligent will, over the rugged hostility of matter; is the ardent love of eternal science, the sacred desire of revealing the mysterious laws that govern universal life. Perhaps, too, it is the noble ambition of the 'lord of creation,' who, by a free and courageous act, wishes to engrave in his conscience—on the last mountain-peak added to the known world—and in the face of the Unknown which expands before him, the seal of his kinship with the Infinite."

For, in the contemplation of Nature, the soul grows purer, the mind more elevated, and the heart more sensible to sacred influences. It was a knowledge of this truth which induced the poet to exclaim :—

"And I have felt
A presence that disturbs me with the joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean, and the living air,
And the blue sky, and in the mind of man!
A motion and a spirit that impels
All thinking things, all objects of all thought,
And rolls through all things."—WORDSWORTH.

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